PRINCIPLES OF CROP HUSBANDRY IN INDIA

BY

A. K. YEGNA NARAYAN AIYER

(3)

₹ २०/-
6/7/65

२

1. main
2 Auilin
3 [illegible]
4 [illegible]
5 [illegible]

[illegible]

PRINCIPLES OF CROP HUSBANDRY IN INDIA

PRINCIPLES OF CROP HUSBANDRY IN INDIA

BY

RAJASEVASAKTA

A. K. YEGNA NARAYAN AIYER, M.A. (Madras)

Dip. in Agric. (Cantab.), N.D.D. (England)

Director of Agriculture in Mysore (Retired)

Ex-President, Indian Science Congress, Section of Agriculture; Special Duty Officer under the Indian Council of Agricultural Research on several occasions; Member, Commodities and Dairy Science Committees of the same Council; Examiner in Agriculture for many years in the Agricultural College, Coimbatore; Editor, "The Monthly Bulletin of the Bangalore Dairy Cattle Society"; Chairman, Agricultural Committee of the Mysore Economic Conference, etc.

Also Author of
"Field Crops of India"
"Co-operation and Indian Agriculture"
"Feeds and Fodders", "Milk and Milk Products" and other works

PUBLISHED BY

THE BANGALORE PRINTING & PUBLISHING CO., LTD.

MYSORE ROAD, BANGALORE CITY

1963

checked
M.K

ST-97
RG1

ST

TO

HIS HIGHNESS

SRI JAYACHAMARAJA WADIYAR BAHADUR

G.B.E., G.C.S.I.

GOVERNOR OF MYSORE

THIS BOOK IS MOST RESPECTFULLY DEDICATED
WITH HIS HIGHNESS' GRACIOUS PERMISSION
AS A HUMBLE TRIBUTE OF LOYALTY
AND GRATITUDE

BY

THE AUTHOR

First Edition	1948
Second Edition	1953
Third Edition	1957
Fourth Edition '	1963

PRINTED AT THE BANGALORE PRESS, MYSORE ROAD
BANGALORE CITY

PREFACE

NOTHING is more characteristic of present-day Indian conditions than the grave concern over the shortage of food in the country which it is feared may become a permanent feature unless strenuous and well-planned practical measures are adopted all over the country in order to increase production to meet not only the present scarcity but also the needs of a rapidly growing population, with a higher standard of living. The situation is not indeed confined to India but happens to be a world feature, and co-ordinated schemes for adequate production and equitable distribution are being examined and planned by international organisations. The interest aroused at the present time in agriculture, both in respect of crop husbandry and animal husbandry including dairying, is thus world-wide and in India it is closely related to an immediate and pressing need. Large and costly schemes have been drawn up and are being put into operation by both the Central and Provincial Governments in India, for bringing more land under cultivation, for extending irrigation, and for intensifying and increasing the level of production by all well-recognised methods. Agricultural education, research and popularisation are also receiving very great attention, as part of these endeavours. The public, both rural and urban, to whom even at the best of times agriculture makes but a languid appeal, have awakened to the situation and are eager to respond to and co-operate with the Governments in these endeavours, and it may be said on the whole that agriculture has leapt into a position of first-rate importance from one of comparative neglect.

The author has often felt, and has no doubt that others have had the same feeling, that side by side with these developments there exists a great paucity of suitable books which deal with Indian Agriculture in all its important aspects in a somewhat popular manner which may be found useful to both students and the interested public alike. This paucity becomes very conspicuous when we see that in other countries and especially the U.S.A., there is a steady flow of such books and other publications of varying grades and scope becoming available to the public who, the author can testify by personal experience in the States, derive much valuable practical help and guidance from them. In India, although the printed page can reach only a small fraction of the people, still the handicap imposed by this paucity is a serious one. With the exception of the very valuable and well-known text-books by J. W. Molison and N. G. Mukerji, both of which are rather old (although their usefulness remains unimpaired), there are hardly any compendious books of a similar character available, although much useful information on a variety of important subjects is published through the medium of bulletins, pamphlets and the various agricultural journals.

In view of this circumstance the author made bold to write and publish recently his *Field Crops of India* in the belief that it will meet a real need, and the reception which it has received has more than justified this belief. He has felt however that a companion volume to this book was called for, in order to supplement it with one which will deal with the scientific foundations which underlie the various cultivation methods described and which will give at the same time an over-all picture of all the factors concerned in crop production. He has accordingly ventured to bring out the present publication. The main objective of the book is still the practical one, of how best these factors can be made to operate in the positive direction of increasing crop production; such scientific aspects as have been dealt with are only for making one understand the why's and the wherefore's of the methods, so that variations or adaptations may occur to the minds of thoughtful readers, which may prove real improvements and thus help the cause of agricultural progress. Care has been taken throughout to confine attention to Indian conditions, though mention has been made here and there of those prevalent elsewhere also, where they may be deemed applicable to India or prove thought-provoking as to why we should not do likewise in this country.

The scope of the book will be seen in broad outline from the Chapter headings and more particularly from the sub-headings, which have been included in the "Contents". It will be seen that not only are all the factors of crop production dealt with but that in addition one chapter has been included dealing with Crop Husbandry as a Business, so that the financial and marketing aspects of crop raising are also gone into, as a fitting close to the various chapters. In the treatment of the subject-matter, a sort of middle course has been adopted in order to make the book useful to as large a section of the public as may be desirable, and much scientific matter and many technical terms of the kind usually found in text-books have been kept at a minimum. For the same reason the general principles have been dealt with rather than many operations or methods requiring much specialised knowledge such as the methods of laying out manurial and other experiments and their statistical interpretation, the technique of plant breeding, and so on. Special books on these particular subjects will have to be consulted by those who wish to go into them further. For the purpose intended however the author trusts that this feature will in no way lessen the usefulness of the book; indeed in a book of this kind dealing with such a variety of subjects and with the objects set forth any other course is hardly possible or advisable.

Foreign readers may find the implements and appliances dealt with crude and primitive, but under the peculiar conditions in which they are used and have to be used, most of them will be found to do surprisingly good work when their simplicity and cheapness are also considered. The use of tractors in Indian Agriculture—which is

now claiming much public attention—for tillage, road haulage and belt work has been dealt with in some detail, the past history of tractor or engine ploughing in this country has been reviewed and the scope for the newer outfits discussed together with their limitations and the difficulties to be overcome. This subject will be found dealt with in two places, *viz.*, Chapters IX and XXII, according to the kind of work for which tractors are considered desirable. In some instances the subject-matter will be found fuller than is usual in the books available on the subjects, *viz.*, Rotation of Crops and Mixed Cropping. The author was deputed sometime ago by the I.C.A.R. to write a monograph on "Mixed Cropping" and in the course of the work had to collect information from all parts of India on the methods prevalent in the various Provinces and States. From this collection a fairly large number has been selected and incorporated in these two chapters. A full list however will be found in the monograph itself (which awaits publication).

The information brought together in the book is largely based on the author's own personal experience, which relates to the State of Mysore intimately and to many other parts of India and foreign countries like Europe and the U.S.A. Since his retirement from the office of Director of Agriculture in Mysore he has also been in close touch with agricultural development and problems in various capacities and continues to do so still as the Chairman of the Planning Committee for Agriculture under the Government of Mysore—an advantage which has been fully utilised in preparing the book.

Both in the practical aspects of the subject-matter dealt with and in what may be termed the scientific aspects, several standard books on the various subjects have been consulted in addition to journals, bulletins and reports. Some of the figures relating to work in Mysore, such as for example, the soil moisture determinations and the composition of some of the soils and manures, are the author's own. In the case of many other items of information, especially of a scientific character, the source has been indicated and acknowledged in the text itself. A full list of the books and other publications consulted is however given in Appendix II. The author takes this opportunity of gratefully acknowledging his indebtedness to the various writers for the information which has been made use of.

The author feels that despite the pains taken errors and imperfections may be noticed in the book but trusts that they may not be such as will detract from the usefulness of the book.

The author feels very thankful to the Director of Agriculture in Mysore, to E. J. Baker, Esq., President, *Farm Implement News*, Chicago, U.S.A., to Messrs. Kirloskar Bros., to the fertiliser manufacturing companies, Messrs. Travancore Fertilisers and Chemicals, The Mysore Fertilisers and Chemicals, Messrs. Aeromotors, Chicago, Messrs. Sigmund Pumps (Great Britain), and to the Editor, *Daily News*, Bangalore, for their courtesy in lending their blocks of illustrations for use in the book. Their courtesy is further acknowledged under

the respective illustrations. Many friends have helped him in other ways: Sri. T. V. Ramachandra Aiyer, B.A., F.R.MET.S., has seen through the chapter on Climatic Factors, Sri. C. N. Shama Rau, B.E., Superintending Engineer in Mysore, has furnished the costs of power in pumping; Sri. N. Krishna Iyengar, B.A., of Ooragahalli Estate, has furnished the data on the work of the two tractors on his estate; and *Panditabhushana* V. Subramanya Sastri, B.A., has helped with his English translation of the book *Brihat Samhita,* extracts from which relating to 'weather forecasts', and 'selection of sites for wells' are given in the concerned chapters. Many other friends whom he has had to consult have also gladly helped him. The author is very much indebted to all of them and would express his grateful thanks for the help received. He would also express his great appreciation and thankfulness to the Bangalore Press and its Superintendent, for the excellence of the get-up of the book and the promptitude with which the work was executed.

PREFACE TO THE SECOND EDITION

THE author is much gratified that this book has been found useful not only by students but also by all those interested in Indian Agriculture and that it has evidently met a real need. The demand has been keen enough to call for a second edition which is accordingly being now published.

The new edition is almost entirely a reprint of the earlier edition, as indeed it cannot be otherwise, because the period which has elapsed since the first edition was issued has not been long enough for any material changes or important results of scientific work which ought to find a place in the new edition, at any rate such as may be deemed appropriate in a popular book of this kind. Nevertheless, a few additions have been made here and there. Thus, one addition is a brief note on what is called "Electroculture". Although the role of electricity as a factor in crop production and the methods of its application in practice are both not well understood and although the results recorded are not well accepted and are more or less of the 'believe it or not' order, still such as it is, it deserves a place in a book dealing with the various factors of crop production. The note, therefore, may be said to supply an omission in the first edition. Another addition is the subject of 'hydroponics', especially in relation to manuring, which presents some interesting features worthy of being carefully studied and of which little more than a brief mention was made in the older edition. Further, in view of the new synthetic chemical insecticides and fungicides which are now being put out in large numbers and under a bewildering variety of trade names, reference has been made to some more of them than were touched upon in the older edition. All these additions, are, however, very minor in character but it is hoped they may increase the usefulness of the book.

A few changes have had to be made in the illustrations; some have had to be omitted and others added, the noteworthy one among the latter being a panoramic view of the mammoth fertiliser factory at Sindri.

It was stated in the first edition that the author's monograph on "Mixed Cropping" prepared for the Indian Council of Agricultural Research had not been published. It has, however, since been published and copies can be obtained from the Bangalore Press.

The author takes this opportunity of expressing his grateful thanks to all those who have kindly supplied blocks or photographs for the illustrations and to the Bangalore Press for the neatness of the get-up and the promptitude of execution.

PREFACE TO THE THIRD EDITION

THE third edition is almost entirely a reprint of the second edition. A few minor additions which refer to recent work have however been made here and there, so as to bring the information more or less up-to-date. These relate to subjects like the Overhead or Sprinkler method of irrigation, the 'Filter-point' pumping installation, the use of liquid ammonia as a fertiliser, and some of the new methods of insect control. It is hoped that these will enhance the usefulness of the book and that the present edition will be as popular as the earlier ones.

CONTENTS

LIST OF ILLUSTRATIONS

CHAPTER I

CLIMATIC FACTORS IN INDIAN AGRICULTURE

AGRICULTURE is subject to the influence of a large number of factors, some of which are capable of being controlled and others are beyond the control of man. The principles and methods of successful farming relate generally only to those factors which can be controlled, and it is therefore these factors which form the subject dealt with in these pages. Reference must however be made to the factors beyond the control of man which prove either helpful to the efforts of man or positively harmful and neutralise or render them infructuous. These factors are the various components of what is summarised as 'climate' which is the combined result of factors like the situation of the tract within the terrestrial zones, the rainfall, temperature of the atmosphere, sunshine, winds, snow, frost, and so on. These factors constituting in their yearly aggregate the climate of any tract set and inexorable limit to the kinds of crops that can be grown, the seasons in which they can be grown and even the methods of growing them. It is only within the limit imposed by climate that crop raising in all its aspects can be carried on. Though in the main these factors are beyond human control, it is to a certain extent possible to mitigate their rigour, successfully overcome them to a certain extent and even to carry out measures which will amount to controlling them in a sense.

GEOGRAPHICAL POSITION

The first of these factors is the geographical position of the country. India extends from about the 8th parallel of latitude to about 35th parallel N. and therefore lies partly in the tropical and partly in the north temperate zone. This makes it a home suitable for a great variety of natural vegetation. It also makes it possible for plant life to grow throughout the year without any cessation or hiatus as in the case of countries situated in high latitudes where growth comes to a standstill in the winter. Although during the very hot summer months, tree life adjusts itself to the hard conditions by a shedding of the leaves and a short and sometimes very brief and almost imperceptible period of rest, growth is however possible wherever water may be available. The result is that provided water can be had for irrigation crops can be grown throughout the year within these zones.

Other important physiographical features confer additional advantages. First among these is the proximity of the sea which is enjoyed by the immense tract of coastal country washed by the Arabian Sea on the west and the Bay of Bengal in the east and north-east. Many important crops which have an island habitat or are largely favoured by proximity to the sea, like cocoanuts, arecanuts, pepper, clove and a large number of tropical fruits, flowers and

edible tubers can therefore be grown over large areas of the country. The next is the advantage conferred by the high elevation of extensive regions situated on both sides of the western ghats and its numerous spurs, which enjoy a mild climate through a great part of the year and a distinctly cold climate during the winter months. To a smaller degree the same advantage is possessed by the several plateaus which traverse the country both in Central and in Peninsular India. The mild climate of these regions makes it possible to grow crops of the colder zones of the globe sometimes reaching almost the same degree of perfection. Though these features mitigate the limitations set by the geographical zones, each zone is adapted only to the particular kinds of crops which are suited to it and large as the country is, and extending far away from the tropics, the climate set by the location excludes quite a number of crops that are native to or grow to perfection only in colder latitudes.

RAINFALL

The next factor of production which is beyond the control of man is the rainfall. There is no single requirement of plant life which is more vital than the provision of water, adequate quantities of which should be readily available within the root zone of all kinds of plant life. Such water may be present in the soil naturally, or be supplied by irrigation or be derived directly from the rainfall during the crop season. Directly or indirectly the rainfall (in which may be included snowfall) is the source of the water that is available for crops or other vegetation and the success in crop raising is in direct proportion to the supply of the necessary quantity of water at the times when it may be required. The innumerable irrigation systems in the country, both small and large, all aim to satisfy this paramount need in crop production. Irrigation not only supplements the rainfall but also helps to correct inequalities in the distribution of the rainfall, which may be abundant when not needed and scanty when needed. Large as these systems are and larger still as are those which are planned for the future, the extent of country which they can effectively protect can be only a small percentage perhaps less than 20%, of the total area under crop. The large bulk of the country will therefore have to depend solely and directly on the rainfall, *i.e.,* to be put only under dry cultivation. If the rainfall is sufficient and well distributed then crops succeed and the husbandman's efforts are rewarded; if the rainfall is low or if it is badly distributed even when the total quantity is high, then crop reduction of varying degrees occurs, including total failure. It is one of the saddest features of Indian agriculture that so much should depend upon the nature of the yearly rainfall which is a factor so absolutely beyond human control. The position as regards rainfall in India may now be described.

Rainfall in India.—The rainfall in India is peculiar in the fact that it is connected with the monsoon winds, much more than with

the real season of winter. The rainfall in most parts of the country occurs in the so-called summer months, *i.e.*, from the month of June to August and in other parts in the late autumn and early winter, *i.e.*, the months of October to December. The rainfall is closely associated with the two monsoons, the S.W. and N.E., and there may be thus said to be two distinct rainy seasons. From June to August, the S.W. Monsoon winds blow from the south-west and carry with them rain-laden clouds; these clouds burst on the western coast and on the western ghats, pass over the ghats in a greatly depleted condition and extend eastwards in the so-called rainshade of the ghats far or near according to the strength of the monsoon. The coastal region from Bombay southwards to Cape Comorin is a tract of very heavy rainfall, as indeed to a comparatively less extent the adjoining ghats on its eastern side. The rainfall is concentrated in these three months and tails off and disappears almost entirely from September onwards.

During the same season the tracts on the coast of the Bay of Bengal, roughly north of the 16th N. latitude and extending into Bengal and Assam, receive the bulk of their rainfall, from rain clouds from over the Bay, and some of the tracts (like Cherrapunji) are also centres of torrential rainfall. The same rain extends into the interior, either from the Arabian Sea or from the Bay of Bengal and the whole of Upper India receives its main rainfall in the same season. The coastal districts of South Madras on the other hand receive their rainfall in the N.-E. Monsoon during the months of October to December. This monsoon travels more or less according to its strength to interior districts which receive part of their rainfall during this season.

Some of the districts of Peninsular India thus get the benefit of both monsoons if both are sufficiently strong, and some on the other hand are so situated that they get the benefit of neither and are more or less subject to famines frequently. The north-western tracts of Sind, the Frontier Province and even parts of the Punjab and Rajputana are reached by neither monsoon and are the regions of lowest rainfall in India, the quantities being hardly worth mentioning. Cropping is impossible in these tracts without irrigation, and much of the tract is as a matter of fact desert country. The general rainfall of India during the several months of the year may be described as from nil to insignificant quantities from January to June, heavy to moderate and more or less concentrated in the months of June to August, light in September, and heavy again in the months of October to December. The following is a more detailed description of the different zones of rainfall in India. "The west coast is fringed with a belt of very heavy rainfall where the westerly summer monsoon blows full upon the land. At a distance of 50 miles or less from the sea a hill range (the western ghats) runs parallel with the coast and over the whole intervening space the rainfall is very high varying from 100" to 200". This zone of high rainfall contracts rapidly to the north of Bombay and dies out at the end of the

ghats, south of the Tapti. In the east however it extends through Eastern Bengal and Cachar and along the face of the Kasi Hills to the gates of Assam where it links on to a similar zone, which runs east to west along the face of the Himalayas. . . . It lessens rapidly as we penetrate farther into the hills until beyond the first snowy range we enter on the dry region of Tibet represented by Leh with an annual rainfall of $2\frac{1}{2}''$.

From the Gulf of Cambay and the Sabarmathi River a band of moderately high rainfall (between 30" and 70") stretches eastwards across India, rapidly broadening out and increasing in average amount in the direction of Bengal. It occupies all North-Eastern India, extends to the valley of the Ganges in the north and basins of the Godavari and Krishna in the south. From Allahabad an offshoot runs up to the plains north of the Ganges through Northern Punjab as far as the Indus Valley. In the south of the peninsula are two outlying tracts with a rainfall of over 30". One on the eastern ghats east of Kurnool; the other including all the central districts of the Karnatic and linked on to the zone of high rainfall of the western ghats and further south across the hill groups between Trichinopoly and Madura.

The rest of India has an annual rainfall less than 30". It consists of (1) the dry N.-W. region (Rajputana, Sind, Cutch, parts of Gujerat and the Punjab) where it steadily decreases in a westerly direction until the minimum is reached in the Cutchee Desert between Jacobabad and Baluchistan; (2) the peninsular dry region comprising Khandesh, Berar, Western Deccan, Southern Hyderabad, the Ceded Districts, Mysore, Coimbatore and the south-eastern plain between Tanjore and Cape Comorin. In these are many isolated tracts like Bellary, parts of Coimbatore and Nilgiris and Mysore and the coast near the Gulf of Mannar, where the rainfall goes below 20"."—[Abstracts from *Climate and Weather of India, Ceylon and Burma*, by H. F. Blandford.]

The total annual rainfall in the different parts of India can be seen from the following statement of the rainfall for a few typical stations :—

	Inches		Inches
Karachi ..	7·8	Nagpur ..	44·7
Jacobabad ..	4·4	Poona ..	28·3
Dera Ismail Khan ..	8·3	Bombay ..	74·4
Peshawar ..	13·5	Karwar ..	116·5
Simla ..	70·1	Mahabaleshwar ..	261·1
Delhi ..	27·6	Belgaum ..	48·8
Lahore ..	21·1	Secunderabad ..	28·8
Agra ..	26·2	Bellary ..	17·6
Indore ..	36·1	Bangalore ..	35·5
Allahabad ..	37·6	Masulipatam ..	38·5
Patna ..	42·6	Madras ..	49·1
Darjeeling ..	120·3	Trichinopoly ..	37·1
Calcutta ..	65·5	Cuddapah ..	28·3
Silchar ..	120·0	Mangalore ..	131·0
Cherrapunji ..	474·0	Cochin ..	115·1
Cuttack ..	58·4		

Distribution of Rainfall.—The total rainfall of the year is not however an index of the benefit derived therefrom for purposes of crop raising. Most of the rain is concentrated in the monsoon months, as already explained. Furthermore even where the number of rainy days is fairly large, the distribution as between these days is very uneven, many days in the monsoon being days of torrential rainfall and the rest of only insignificant showers. In consequence of this character it is less penetrating in proportion to its quantity and large portions of it flow off the surface through the streams and rivers and are wasted, instead of "feeding perennial springs and nourishing an absorbent cushion....of green herbage" (Blandford). Nevertheless from the most ancient times efforts have been successfully made in India to control this character and harness the water for the use of agriculture by the construction of irrigation tanks, small and large, almost limitless in number in which this flow is dammed up and the water stored during the rains to be later used for irrigation. This is certainly the most efficient form of control, exercised over such an uncertain and uncontrollable factor as the rainfall.

Although with an even and favourable distribution most of the dry crops of India can be grown to maturity with a rainfall of about 20" including the period for preparing the soil, crop failures are frequent in spite of the annual rainfall being much in excess of this requirement, solely because of the uneven distribution. It has also been found that the yield of particular crops depends principally upon the rainfall of particular months or periods in its growth, say the period of the appearance of the earheads or the period of the milk stage, and a good shower at this period will make all the difference between a good and a bad yield. In the case of ragi, for example in Bangalore, this period has been found to be the months of October and November. Prolonged periods of rainless weather during the vegetative stage of the growth also put back the growth. Most dry crops in ordinary cultivation must be considered very drought-resisting and when even these fail in a year when the annual rainfall is not below the average, it is due to the uneven distribution during the crop season.

Through selecting suitable crops and adopting special dry farming methods much can be and is being done to mitigate the risks due to the uncertain and uneven rainfall. Despite all possible agricultural operations to combat the risk, rains may fail at critical periods and render all efforts of no avail. Sometimes after the fields have been well prepared and got ready for sowing with favourable early rains, a sowing rain may hold off preventing the sowing at the correct time or delaying until the season is past altogether, or rain may hold off at other critical times in the growth of the plants mentioned already. In the case of a crop like coffee, the blossom showers may hold off too long or, after the blossoms have appeared rains may

hold off which may result in the berries not setting. Similar instances in respect of other crops are very common.

Artificial Production of Rain.—Under these circumstances, it is a question if rain cannot be artificially produced. Such a rain is not for the crop season or such prolonged period but only an emergency shower to tide over a critical time—the rain in fact which makes all the difference between a crop and no crop. Much success seems to have attended the attempts at the artificial production of rain, so that the idea is no longer fantastic but is capable of being profitably adopted in practice. It may be of interest to describe some of the experiments carried out in recent years, especially after the use of aeroplanes became common. The artificial production of rain is based upon the natural process which takes place in the upper atmosphere. In these regions there is moisture always present but in the form of minute drops so light that they remain in suspension. Electrically charged dust, when shaken on to this zone of moisture, brings the moisture particles together in aggregated masses which now become too heavy to remain in suspension and begin to fall as rain. Clouds formed as vapour too light to fall as rain are thus weighed by electrically charged dust and soon disgorge the moisture as rain. It is stated that in this method about 40 lb. of electrified sand would be sufficient for being dropped by an aeroplane over a square mile of clouds in order to cause the moisture they carry to come down as a rain. Prof. Warren and Prof. Bancroft, two American scientists, are reported to have developed this method and to have given a spectacular demonstration of its success and practical value.

In another method attributed to the Dutch scientist, Prof. Veraat, dry ice (solid carbon dioxide) is substituted for the sand and is sprinkled from an aeroplane on to the bank of clouds. In one demonstration Prof. Veraat rose to a height of 2,500 metres (about 8,000′) in a plane carrying 1½ tons of dry ice and let the powder fall spreading on to clouds 200 metres (about 650′) below, causing abundant and immediate rain (*La Meteorologia Practica,* 1931, Anno XII, No. 5, pp. 256–58).

In a third method, silver iodide in the shape of exceedingly minute crystals is employed instead of dry ice, for 'seeding' the clouds and acting as nuclei round which the moisture can freeze. The material is introduced into the clouds either as a smoke rising very high in the sky or as a spray or dust shot down from high flying aeroplanes. Once the cooling action is started it progresses by a kind of chain reaction, until the effect permeates throughout the cloud mass and the moisture descends either as rain or as snow depending upon the atmospheric temperature below the cloud layer. The subject and the accounts of successful artificial production of rain are generally received with mild scepticism, if not of suppressed ridicule, but sufficient progress appears to have been made to lift it out of this state and endow it with practical usefulness. Remarkable accounts have been published within the last two years of strikingly

successful 'rain-making', which are associated with the names of Dr. Irving Langmuir and of Dr. Irving P. Krick in the U.S.A. The methods have even been commercialised; for, farmers, power companies, and water-supply corporations are said to be seeking the aid of 'rain-makers' in times of dire need, and questions regarding the rights of States to the use of clouds within their limits and of the moisture therein as against 'poaching neighbours' have even been raised. Trials in India are eminently desirable and the usefulness of the method, even if it should be very limited, can still achieve much, in view of what has been said above on the need and importance of a shower of rain at a critical time.

Excessive and Untimely Rainfall.—Although the shortage or failure of rainfall at the proper time is the more common occurrence unfavourable to crop production, an equally damaging effect may be produced by too heavy rainfall and at times when it may not be wanted. Heavy rains immediately following sowing, or continuous rains even if light when the sown field has to be hoed and weeded and the soil has to be fairly dry for the operation, heavy rain during the growing season making the soil water-logged and the growth of the crop yellow and sickly, heavy rain at the time when the flowers are opening and fertilisation has to take place but which will be reduced or prevented by the washing away of the pollen, and again at harvest time, delaying the harvest and causing the shedding of the grain, or if harvested nevertheless, making the grain mouldy in the stack,—in all these ways heavy or unseasonal rain may greatly damage the crop and reduce both the yield and the quality of the produce. Particular crops may be damaged in special ways, such as tobacco if it should rain when the leaves are ripe and ready to harvest and are covered with a resin or sticky matter on the leaf surface which may run the risk of being washed away; coffee and many fruit crops will suffer if there is heavy rain when the fruits or berries are ripe and ready to gather, cotton when the bolls open and are ready to pick and so on. In other ways also damage may be caused such as by the occurrence of insect pests, and fungoid diseases. Bright weather is also needed for the preparation of the crop, such as the threshing of grains, the drying and curing of coffee, tobacco, turmeric, pepper and arecanut, the milling of sugarcane, and preparation of jaggery, and rainy weather will greatly interfere with these operations and result in diminished yield and quality of product, or necessitate special expensive arrangements such as artificial drying, covered structures and so on, for conducting the operations in spite of the rains.

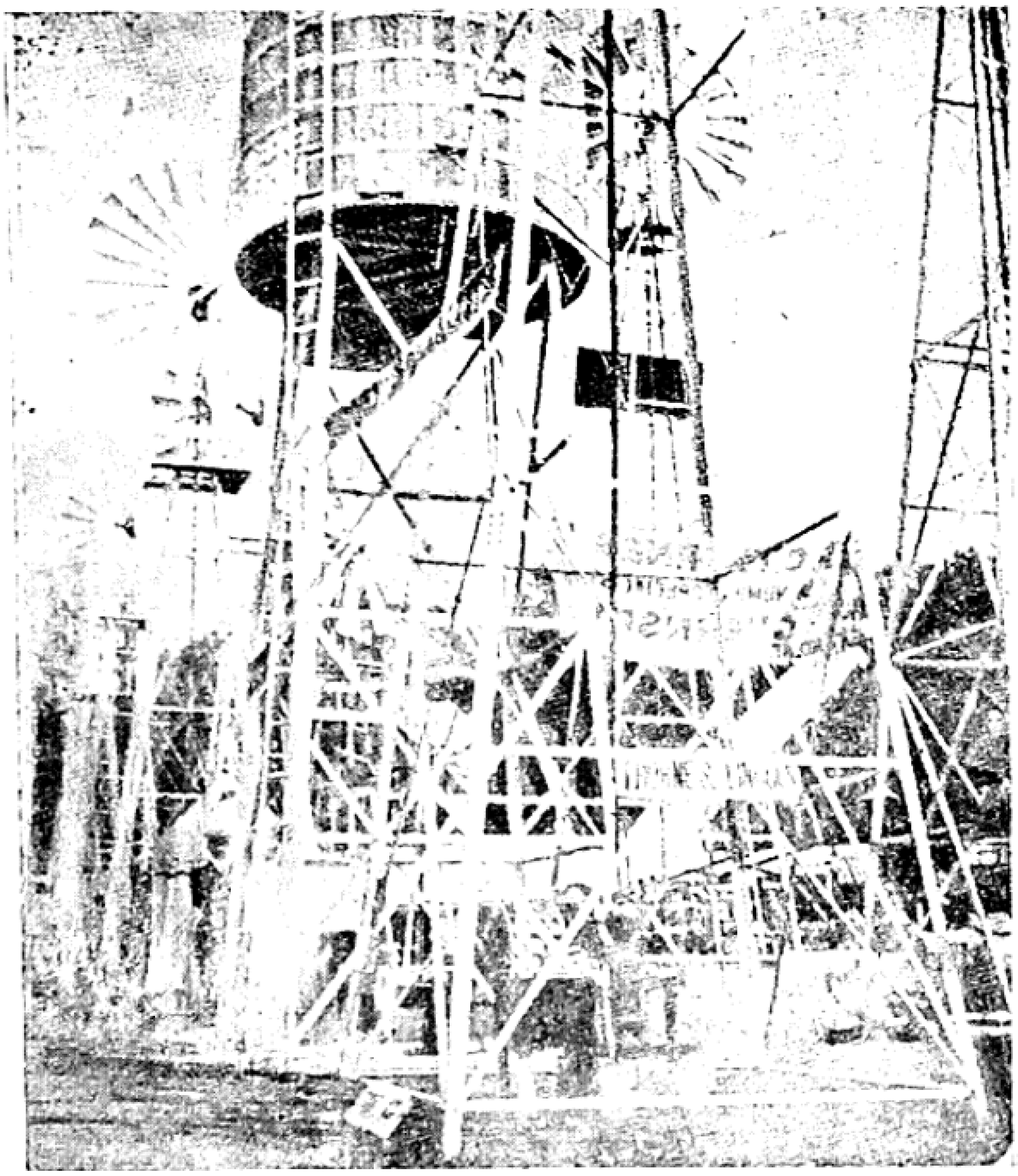
WINDS

The next meteorological factor which influences crop production and which is also beyond the control of man is the wind. Though the effect of the wind as a factor by itself is of very little significance as compared with the rainfall still it may, under certain circumstances,

have the most damaging effect and lead to even total destruction. In India, however, the winds are closely associated with the rainfall and it is the monsoon winds that carry the rain-laden clouds both far and near and are responsible for the distribution of the rainfall over the country as already explained and has therefore to be considered a highly important and beneficial factor. By itself the wind is more generally a very unfavourable factor. Dust-laden dry winds precede the monsoon and can cover both crop and land with a coat of fine dust, or if it blows over river sand or desert, can do serious damage by laceration or abrasion of leaves and stems. Permanent damage can also be caused by the formation of sand dunes over otherwise fertile country. High winds can blow down tall-growing crops or tear off branches, lay low grain crops in ear, or cause the wholesale dropping of fruits in all stages. It is of the utmost importance that suitable 'wind-breaks' formed either by a belt of tall-growing trees or by fences and hedges of varying heights suited to the nature of the crops to be protected should be provided across the track of the prevailing wind so as to break its force and safeguard the crop. Orchard crops, areca gardens, betel leaf gardens, plantain gardens, sugarcane fields, etc., all require the strong protection of such a belt of trees or hedges. In the case of crops like the plantain, even additional protection will be necessary, in the shape of suitable props to the individual trees during the months when they are carrying fruit bunches, in order to prevent them from falling over. Fierce winds, like storms and cyclones, may devastate whole regions and in the regions subject to the occurrence of these visitations, special protection has to be afforded to tall-growing crops like sugarcane, by furnishing them with an efficient system of propping. Visitations occur periodically which ruin at one fell blow the work of many years by uprooting large trees and ruining permanent plantations of cocoanut, mangoes, etc., and committing havoc which may take many years to repair. Cyclonic storms in India are more common along the coast of the Bay of Bengal than on the Arabian Sea Coast. Not infrequently such storms especially in the early monsoon are accompanied by hailstorms, both large and small, and great damage may be caused to fruit trees, and the fruit crops both by their being blown down and being pitted and damaged.

High winds can also damage by erosion or the removal of the soil to varying depths according to the nature and the force of the wind. High whirling tornadoes can churn up the soil and carry it away in clouds to long distances, thereby denuding the fields down to the hard pan or even rock. Such erosion may even necessitate the abandonment of the farms altogether.

Dry winds are responsible for the drying up by increased evaporation, the soil moisture from the surface down to varying depths and this drying action will have to be guarded against by the creation of a rough soil mulch of clods of ploughed fields or in the case of irrigated crops by a more plentiful irrigation. The wind is also a



Utilization of wind power—Wind mills or Aero-motors of different types: collection exhibited at the Royal Agricultural Society's Show, Norwich, England.
Photo by Author

factor in the spread of certain crop diseases, the spores of which (as in the case of the different rusts of wheat and other grain crops) can be carried long distances through the agency of the wind. A similar but more beneficent function is also performed by the wind in motion, when it carries pollen and fertilises crops or carries the seeds of many kinds of forest vegetation leading to a natural regeneration. The seeds of weeds may likewise be borne by the wind over long distances and lead to infestation over new areas. Winds of the cold weather are sometimes very cold and spells may occur when crops are in flower and may either delay fertilisation or prevent it to a large extent leading to a reduction in yield of such crops.

Velocity of the Wind.—Wind velocities in India are very low during the greater part of the year and in Upper India are low practically throughout the year. The monthly means even during the so-called windy months seldom reach more than 8 miles an hour in this region. Elsewhere the velocities are fairly high but this is only in the months from April or May to August or September, and even then, the monthly mean does not reach more than 20 or 22 miles an hour, and is generally around 12 or 15 miles. On the coast of Madras however such winds prevail over a larger part of the year, *viz.*, from April to September and again from November to January. The wind has practical importance in agriculture as a possible source of motive power as in the use of aero-motors or wind-mills for driving irrigation pumps. The above features however very largely restrict the scope for such use, because in Upper India the wind velocities are too low and elsewhere only particular months are suitable, and these happen to be mostly the months of the monsoon rainfall and not the rainless months when irrigation is most needed.

The mean monthly velocities of the wind are approximately as below for some selected stations in India :—

Station		Months	Approximate maximum miles per hour
Calcutta	..	April, May	8
Dacca	..	April to September	8
Agra	..	April to September	7
Lahore	..	July, August	6
Peshawar	..	April, May, June	5
Karachi	..	April to September	22
Bombay	..	March to August	12
Poona	..	May to September	17
Bangalore	..	May to September	21
Madras	..	January, April to September and November to December	16
Vizagapatam	..	Do.	14

(Taken from *India Weather Review*, 1939, figures rounded.)

Atmospheric Temperature.—Some of the above effects of the wind are usually intensified by the atmospheric temperature which increases the drying effect when it is high and the growth-inhibiting or delaying effect when it is low. If the temperature goes low even

frosts may set in and if these occur when the buds are opening or at other critical time then serious damage may result.

Atmospheric temperature in India is characterised firstly, by the high limit it reaches in the hot weather months in many parts of the country and secondly, by the very large variations between such maximum and the minimum that may be reached in the cold weather months. For example, the maximum reached on any particular day in the year and the minimum likewise were as below in the following typical stations :—

Station	Maximum ° F.	Minimum ° F.
Silchar	98	48
Calcutta	107	45
Patna	111	46
Agra	115	37
New Delhi	114	27
Jacobabad	123	37
Kotah	113	46
Indore	107	40
Nagpur	114	45
Bombay	96	64
Hyderabad (Deccan)	110	46
Bangalore	95	52
Calicut	93	66
Madura	105	65
Madras	110	60
Bellary	108	56
Vizagapatam	104	61

(Figures relate to the year 1939, taken from *India Weather Review*, 1939.)

Mitigation of High Temperature Effect.—Crops naturally suffer from the drying effect of the high temperatures and in many cases some control has to be exercised in order to reduce this effect and protect the crop. This is afforded by the planting of shade trees, the canopies of which afford protection from the sun or of plantains which are generally planted as nurse trees specially for the purpose. Atmospheric temperatures inside cropped fields are considerably lower than the temperature in the open. In experiments in Poona in fields of sugarcane the difference recorded at ground level was 14° F. Similar material difference was noted in the case of the jowar crop also. In special cases as in the betel leaf gardens in Upper India, the gardens are practically thatched over, while flowers and fruit gardens are given an overhead cover of brushwood, cocoanut leaves, etc., like a kind of lattice, affording enough shade without cutting out light; nurseries and young crops of fruit trees particularly need this protection. In certain cases even large trees are protected against the heat of the western sun, by a covering of dry leaves, etc., or of a coat of whitewash on the stem exposed on the western side.

Mitigation of Low Temperature Effect.—Damage due to low temperature is rather uncommon in India and the protection against it is not therefore important except in the far north. Occasional

frosts do occur elsewhere also as around Poona, when large orchards of grapes are damaged, buds being killed and whole branches also blackened and withered. In cold countries however, as in the great orchards of the U.S.A., frosts are a serious and frequent menace and special measures have to be taken to prevent or reduce the damage. With a well-organised and efficient weather-forecasting agency, it is possible to arrange for a timely warning about the coming on of a frost, and in that case it may be possible to take some protective measures; but very often growers have no means of obtaining this previous information and find themselves unprepared, with the result that the frost exerts its full destructive effect.

The commonest method of combating frosts is to light up low smoky fires in a number of places in the orchard and so to heat up the atmosphere near the ground, reduce the loss of heat by radiation from the ground and prevent the frost setting in. These braziers or other arrangements have to be kept in readiness, so that they can be lighted promptly on receipt of the signal, or the appearance of any sign of approaching frosty weather. The shutting out of cold winds by belts of trees or bushes, acting as a wind-break or by screens, and tall quick hedges for gardens or small orchards will also greatly help in reducing frost injury. Sugarcane, when it is ready to cut, is protected against frost injury by the curious method of "windrowing" which consists in cutting down the crop laying it flat on the ground and covering it up with earth. The liability to frost generally precludes the growing of certain crops or restricts the period of such growth, in these regions; or of doing so only under serious risks. The early potatoes grown in the island of Jersey in order to supply a very profitable early market in London is notoriously subject to frost damage and the author remembers an instance one season when whole fields of potatoes became black with plants killed by frost. Frost is generally more severe on low lying lands than on higher slopes, and for this purpose such situations are avoided for the planting of fruit.

Frosts are however not without something in their favour. The freezing of the ground, especially, of clay soils, breaks up the firm texture and gives it a 'crumb' structure; and repeated freezings and thawings bring about a condition of soil texture which on such soils cannot be produced except by very skilful tillage methods. It is also probable that the extremes of temperature which occur in many parts of India during the day and night every day for months together are of some benefit in agriculture due to chemical and physical action exerted upon soils and rocks in these tracts.

Humidity.—Another striking feature of the climatic condition is the great variation in the humidity of the atmosphere, extremes of dryness and of dampness prevailing in many parts of the country. The humidity is more or less correlated with the character of the winds in the particular region. The driest regions in India lie in the so-called arid or rainless tracts of the N.-W. Provinces, Baluchistan,

Punjab, Sind and Rajputana, while the dampest regions are in the east towards Bengal and Assam. The character of the monsoon rains greatly influence the humidity and in the regions where the S.-W. and N.-E. Monsoon rains are heavy the humidity is very high. The same however is not the case in the N.-W. Frontier Province and near the mountain ranges in the north, where the dampest month coincides with the winter, as in the northern latitudes. Elsewhere in the Indian continent generally the more rainy the month, the higher is the humidity. A high humidity may go up to 97 as in Mercara (Coorg) during the month of July (a very heavy rainy month), 95 in Darjeeling and in the plains in about the same season, in the region of heavy S.-W. rainfall generally the humidity may go up to 85 or 89. On the coast of Madras, and adjoining regions where the N.-E. rains are heavy, the humidity reaches a maximum in the months of October-December which is the season of the highest rainfall. The low humidity, *i.e.,* extreme dryness may drop even to 25 and will average about 30 in the Gangetic Plain and Central India generally and this coincides with the dry or rainless months of March and April. Proceeding towards the N.-W. however the driest season advances towards May-June and the same is the case in the central parts of Deccan and the peninsula generally where the lowest humidity occurs in the rainless season extending from March to June.

The extremes in the humidity which occur in one and the same tract are as noteworthy as the rainfall and atmospheric temperature, *i.e.,* in most parts of lower Bengal the range of variation may be approximately between 50 and 80; in the Central Indian plains from 20 and 75; in Coorg from 60 to almost saturation; in Bangalore from 50 to 77; in Secunderabad 36 to 75; Sholapur from 26 to 70. In the south of the peninsula, however, the range is lower; thus, in Madras 60 to 79; in Trichinopoly 54 to 76; in Coimbatore 52 to 75 and in Madura 60 to 75. It will be observed that the humidity conditions are such that they accentuate the drying effect of the atmosphere in the dry seasons, making the conditions for plant growth harder and the need for irrigation greater and increases the dampness of the atmosphere in the rainy seasons when plant life is already abundantly supplied with moisture. Plant life as is well known in nature, *i.e.,* the natural vegetation, is provided with adaptation in tissues to make it flourish or survive in the different conditions; but where crops have to be grown, which are not usually natural or native to the tract, the conditions become unfavourable for satisfactory growth. Under special conditions such as growing under glass or other cover the humidity can be and, as a matter of fact, is controlled by special methods, but under field conditions it is as impossible of control as other climatic factors. Some mitigation is however secured in practice by the growing of shade or nurse crops which will keep the atmosphere cool in the garden, and prevent the free passing of drying winds by the provision of wind-breaks as already explained.

LIGHT

Still another factor of crop production beyond human control is sunlight. As is well known it is in the presence of sunlight that plants are able, with the help of the chlorophyl, to decompose carbon dioxide of the air and assimilate carbon, which is the basic constituent of all plant and animal tissue and is the source of all the energy available on the globe. As a general rule growth is favoured by sunlight and is retarded by the lack of sunlight. Crops or portions thereof, which do not obtain sufficient sunlight suffer in growth, and many agricultural and horticultural practices such as thinning out a crowded or thick stand of crop, removal of excessive shade from trees, the pruning or cutting out of extra branches and such operations have for their object the letting in of more light into the crop.

Insufficient light brought about by excessive shade may put back vigorous growth and induce weak spindly vegetative parts, and may even make the crop more susceptible to diseases. In all but plants which are specially adapted to growing in the shade and are shade-loving in their habit, an abundance of sunlight is a favourable and necessary factor.

The inhibiting effect of shade on plant growth is also taken advantage of in some cases. Much weed growth can be smothered and weakened under a heavy and quick growth of green manure crop like sunnhemp and the different *tephrosias.* Shade is carefully provided and restored when necessary in coffee estates in order, among other things, to suppress weed growth.

Though sunlight is indispensable, the beneficial effect will somewhat vary with the *intensity of the light,* for instance, brilliant sunshine and full exposure to it are not so favourable as somewhat less intensive illumination. Many delicate shades of colour tend to be obliterated and deteriorate into one or two strong single colours in the case of many flowers, in situations or regions where very brilliant sunshine falls on them. Although there are no Indian experiments to go upon, it is held that diffuse daylight is preferable to bright sunshine. On the other hand, in the mild but continuous arctic sunlight, brilliant colours are said to develop much deeper than in the lower latitudes.

The length or period of *duration of light* materially influences the habit of crops, especially in respect of their rapidity or otherwise of growth and maturity. Crops like wheat, rye and barley, when they are grown in the summer of arctic or the far northern latitudes and or therefore subject to almost continuous sunlight are said to grow rapidly and mature earlier than in lower latitudes, where the days are not so long, and also that such maturity takes place even though the atmospheric temperature is as low as 15° F.

Effect of Different Colours of Light.—It is interesting to note that the assimilation process does not take place equally in all

the different portions of the spectrum, *i.e.*, in all the colours. "The plant is not a very efficient transformer of the energy of sunlight, because it only picks out and utilises a very small selection from the numerous rays making up light; according to Dr. Horace Brown's researches, the leaf only succeeds in utilising for the manufacture of starch about 1/1,000 of the energy of sunlight and 1/60 of ordinary diffused daylight" (Dr. W. G. Ogg). The difference in the assimilation process (as measured by the carbon dioxide decomposed) in the different components of the spectrum are of the following relative order, yellow being taken as 100 :—

Red ..	25·4	Blue ..	22·1
Orange ..	63·0	Indigo ..	13·5
Yellow ..	100·0	Violet ..	7·1—(Pfeffer)
Green ..	37·2		

i.e., the assimilation is practically parallel with the brightness in the different components of the spectrum.

The different kinds of light or components of the spectrum appear to affect the growth of plants in different ways, some being favourable and others harmful even to the extent of being lethal. The following interesting results are reported by Mukerji (*Handbook of Indian Agriculture*) in this connection :—"Under yellow light some of the seeds (used in the experiment) did not germinate at all and the plants which did come up soon withered and died. Under orange light, the plants grew tall but had white stalks and did not flower at all. Under red light, the plants grew only an inch or two with something of a red colour but soon rotted and died. Under green light, the plants grew tolerably strong but would not flower. Under blue light, the plants grew and flourished and flowered to perfection just as in the open." The results may have some practical application in the case of plants grown under glass, somewhat analogous to the use of light in chromo-therapy among human beings or the use of blue glass or blue paint in dairies, where this colour is said to repel flies.

In practice, of course, *the control of light and shade* is possible only in the cases already mentioned as ordinary agricultural practices; but cultivation under controlled light or under artificial light is possible in laboratory experiments or on a small scale in the field, and some useful results have been reported under such conditions. Shortening the days to 8 or 10 hours of light, and the growing of rice nurseries under this condition has been reported to have yielded seedlings which when transplanted have matured very much earlier than usual. Late varieties have been made to flower early or simultaneously with early flowering varieties of rice, and artificial crossing for plant breeding purposes between these two varieties made possible. Of course these treatments are possible only on a small scale, but can serve nevertheless a very useful purpose in experimental work.

Long- and Short-day Plants.—Plants can indeed be divided into two classes such as long-day plants and short-day plants, the former growing, flowering and maturing only as the result of long days and the latter requiring only short days. The former are those which usually flower in summer and the latter those that flower in autumn and spring. If the long-day plants are subjected to short-day treatment, then vegetative growth increases and the flowering and fruiting are delayed. If short-day plants on the other hand are given long days by means of artificial light, then flowering is inhibited and they grow into large sizes without flowering. Shortening the day length leads however to premature flowering. In the case of the potato for example this has been found to influence tuber formation. Under such conditions tuber formation is earlier and more abrupt and maturity earlier than under long-day conditions. In the case of jute it has been found that long-day periods of 14-16 hours retarded the flowering and that vegetative growth went on for even 120 days.

SHADE

Shade is not only tolerated but in moderation is found favourable, to certain crops and other vegetation. Coffee, pepper, betel leaf and to some extent ginger, turmeric and the different yams are of the above kind. Ordinary agricultural crops, and the grain crops especially, are however adversely affected; growth may be very poor and may in cases be completely prevented. Fields which abut on the main roads which are lined by large avenue trees suffer particularly by the bad effect of shade, which extends to a considerable distance from the avenue trees (though not generally beyond the outermost edge of the canopy). This effect has to be corrected by the digging of a trench along the side of the field adjoining the avenue, which is based in the belief that the effect is due more to the spread of the root system than of the shade. Even among crops which are benefited by shade, it is not all trees that are so found useful nor are all the shade tolerant or shade-loving plants equal in their preference for particular shade trees. This may be due to the character of the shade, to the nature of the root system or any obscure aspect of the association of crops in nature. Density of shade such as thick, thin or lattice-like, height of the canopy, shape of the leaves and the extent of drip are all factors which decide the usefulness of a shade tree. Other things being equal, leguminous trees are to be preferred. Under some trees certain types of vegetation will not grow and under others not even grass will grow. There is something like natural association of types of vegetation in nature, the underlying causes of which are not well understood.

The provision of *artificial shade* in field husbandry with the exception of the nursery and other practices, referred to already, is very rare. A unique instance is furnished however by the cultivation of wrapper leaf tobacco in the U.S.A. under artificial shade over

hundreds of acres. The shade is provided by structures the roof of which consists of thin wooden slats placed close together, so that a little light can pass through between the slats, or of thin cheese cloth stretched over frames. Tobacco grown under such conditions of restricted sunlight is said to develop very thin and tough leaves and to grow very tall, generally up to 9′.

ASPECT

Attention has sometimes to be paid to the aspect of the field, *i.e.*, the direction or point of the compass which the surface, usually in the case of a gentle slope or hillside, faces. In ordinary flat country as in the plains the matter has little practical importance but on hills and in undulating country and especially in the plantations of permanent crops like coffee, tea, etc., the matter becomes important. In the colder countries like Europe or America the matter is of greater importance. The chief consideration is the extent of the sunshine and warmth resulting therefrom which is received in the different aspects. The warmth of the sun and its duration are very important factors in those cold climates and wherever possible such sunny situations are to be preferred. It is found that the best and sunniest aspects are generally round about the south. In an elaborate experiment by Wollny in Munich (quoted by Storer) in which an artificial mound was erected and the soil temperatures on its different faces (aspects) determined, it was found that in that latitude the warmest aspects were the south-west, south and south-east according as the season was winter, summer or autumn. The western sun even in those cold climates was found to be very warm or warmer than desirable for crops and that the best favoured aspects were the south and south-east.

Although the warmth of the sun is thus the main factor which in those countries decides the aspect, in India in view of the superabundant sunshine and warmth, this factor is not of the same importance. There are other factors like the intensity of the rainfall, high winds, and to some extent cold north winds, which have to be considered and such aspects chosen as afford the largest measure of protection. In these regions the S.-W. Monsoon (both wind and rain) hit the south-western slope in full blast and this aspect is not therefore favourable. The western sun is exceedingly severe often necessitating some special protection for the crops exposed to that direction and a western aspect is therefore not favourable. It is the south, east and northern aspects which can be considered; but the northern aspects both due N. and N.-E. and N.-W. are subject to the action of the cold winds in the winter months and the N.-E. is in addition the direction of the heavy rains, which has considerable influence in the eastern ghats and the east coast region generally. In the plantation districts of the western ghats these rains do not reach to any appreciable extent and do not therefore count much. All these

considered, the S.-E., S. and E. aspects should be regarded as the most favourable in India, while the N., N.-E. and N.-W. are not so objectionable as in colder countries. The importance of aspect as a climatic factor is on the whole one of only minor importance in India.

SEASONS

Vegetation all over the globe is influenced and controlled by the seasons. The plant world wakes up in spring from its winter sleep or hiatus in growth, continues through the summer and autumn to grow and flower and fruit and mature seed, and dies down; or adapts itself to the rest of winter, goes into a kind of hibernation to wake up again and begin another cycle with the advent of spring. The seasons are caused as is well known by the nature of the movement of the earth round the sun; in colder climates the growth cycle strictly follows these seasons and agriculture—ploughing, sowing, reaping—is inexorably governed by them. In those regions, the seasons are very sharply differentiated; the winter becomes too cold to allow plant growth and summer in the principal season for agriculture. Spring and autumn are about intermediate, the early spring and late autumn partaking to a great extent of the cold and unfavourable conditions of winter itself. In India and in the tropics generally the temperature at no time of the year goes too low for plant growth, and crop raising can be carried on during all the seasons. The seasonal conditions are largely influenced and modified by the monsoons and there is vegetation growing on the land, both natural and cultivated, throughout the year; there is not the same outward differentiation of the seasons as is to be seen in the colder latitudes. Indeed in some respects the characteristics are inverted so to speak; for instance, while in the north it is in winter that trees shed their leaves and go into rest for a prolonged period, many tropical trees shed their leaves in the hot summer months and remain leafless only for a very brief period so much so that sometimes new leaves appear almost on the heels of the fallen leaves, with no conspicuous reduction or bareness of the leaf cover. Nevertheless the principle that agriculture should closely follow the seasons is of as great practical importance here as in those countries. It is however not so easy to do so on account of the lack of this sharp differentiation.

The importance of cultivating any particular crop in its proper season cannot be overemphasised. Grown in its proper season, the crop obtains very favourable conditions and may yield a fairly normal crop even if no special care is bestowed upon it. Grown out of season, it may give rise to abnormalities; in extreme cases for example, its vegetative growth may be unduly prolonged, flowering being sometimes even one or two months late and at a very unfavourable time, thus leading to loss; in other cases the reverse may happen, and the crop may flower prematurely when it has hardly made even

half its growth, leading again to loss. Crops out of season become subject to pests and diseases, requiring special treatment and even then may succumb. In many other ways too, growth and yield will be disappointing. Local climatic conditions induce variations in the month of sowing for different crops and it is essential that these should be taken note of and observed. Local experience will be a fairly safe guide in this matter and should not be defied in the belief that by irrigation or other facilities, one could make up for or correct the tendency. This is especially to be observed in the case of varieties of certain crops like rice, jowar, gingelly, many kinds of pulses, etc., among which varieties exist which are strictly suited to and governed by particular seasons.

In India the seasons are broadly two, the season of the S.-W. Monsoon, *i.e.*, sowings in June-July and harvest in November-December. This is the rainy season crop called 'kharif', which is the sole rain-fed crop possible in the region where the S.-W. Monsoon predominates. In the regions where the N.-E. Monsoon predominates the sowings are in October and harvest follows in February-March, this being the sole rain-fed crop in these tracts called 'Rabi'. In places where both monsoons are moderately available, two rain-fed crops can be grown in the same year, the crops being of somewhat shorter duration than in the first or single crop; thus an early monsoon crop sown in April-May and harvested in August-September may be followed by another short season crop on the same land sown in September and harvested in December-January. In irrigated cultivation (principally rice) the main crop is mostly a single crop raised in the S.-W. Monsoon, *i.e.*, sown in June-July and harvested in November-December, the land being bare thereafter. Water may however be stored up in large irrigation tanks, and on the lands under these, a second crop (called summer crop) will follow with the help of the tank water. Indeed where water is available all through the year two or three crops can be taken, the land being never free for more than a few weeks between one crop and another in the year. In these cases it is of great importance that the proper variety suited to the particular month should be chosen and sown.

Nakshatra Rains.—Local practices are based upon long experience and in South India (and no doubt elsewhere also) much guidance is derived from a knowledge of the operations suited to the different parts of the crop year. The crop year is divided roughly into fortnightly periods and comprise 27 "*nakshatra* rains" commencing from the 14th April. The *nakshatras* are the 27 asterisms by which the sun's path is traced from the 14th April during the following twelve months and each of these 27 fortnights is associated with a "rain". Each particular 'rain' has a definite operation attached to it, and is also credited with particular kinds of influence. Some are favourable, some unfavourable, some absolutely essential, and others not so, some favourable to pests, others not, some favourable

to blossoming, others harmful and so on. The "rains" are also divided into 4 quarters or *padas* each, which helps in giving information in greater detail. Agricultural proverbs embodying these beliefs are current in all the languages, and afford much useful guidance, though of only local application to a large extent. For instance, rain in the first *nakshatra Aswini* (from April 14) is definitely bad "destructive to everything", the next or *Bharani* (from April 27) is golden, mother earth will be fruitful, *Mrigasira* (from June 7) is the last rain for sowing early crops. If *Uttara* fails, grain formation will suffer. If *Hasta* fails there will be severe crop failure. If *Chitta* fails pests will increase. *Swati* is ambrosial, men, animals and crops will benefit. With *Anuradha,* the last rain, the ryots' worries end. In the later *'nakshatras'* the rains are regarded as being "nourished in the womb" and if it should rain, it means so much the less rain at a particular *'nakshatra'* in the following year. The author once attempted to see if there was really any such correlation between the rainfall or otherwise during the period of 'gestation' and the rainfall of the concerned *'nakshatra'* in the following year, by a study of the rainfall records of Bangalore for a few years but failed to find any such correlation. The matter is however worth examination more closely by others more competent to do so.

Weather Forecasts

In addition to following the practices which local custom has found out by experience, a great deal of useful help can be derived in the matter of adjusting cropping and agricultural operations to the uncertainties of these conditions from the information supplied by "Weather Forecasts". These forecasts though subject to considerable inaccuracy and sometimes were ridiculed are becoming increasingly accurate and reliable and should be closely studied, as they are published or radioed daily. The occurrence of rains, prevalence of cloudy weather, the approach of high winds, storm or cyclones, the atmospheric temperature likely to prevail, fog signals, etc., are all among the various items of information given by these forecasts in non-technical language. Their chief help consists in enabling one to be prepared for the conditions which are foretold by these forecasts such as, to begin or suspend particular operations or to take suitable precaution in time. There is also considerable weather wisdom among the people generally, gained as the result of long experience which is also found more or less helpful in this respect. The appearance of the cloud formation, the direction of distant thunder, lightning, direction and nature of winds, halos round the moon and even the peculiar habits of animals and the growth of certain plants which react in some special manner to different conditions, afford signs of the kind of weather that may be expected, especially where abnormal or violent changes are threatened and approaching. Though these signs are by no means accurate or reliable to any large extent,

and some may even savour of superstition, still under the limited local conditions under which experience has been gained they will be found to be fairly useful and at any rate not such as could be disregarded without risk. In a matter like the climatic factors in crop production which are so much beyond the control of man and which are yet of such large effect and significance, it will be wise to take full advantage of whatever help that may be available which will enable one to secure as much mitigation as possible.

Forecasts according to Varahamihira.—It may be interesting to draw attention to the ancient Hindu work, the *Brihatsamhita* of Varahamihira, in this connection and the very elaborate study of weather forecasting which that work discloses. The following are some among the 125 *slokas* relating to the subject contained in that work :—

'When a halo resembles the peacock's neck in colour there will be excessive rain.'

'When a thick and glossy halo possesses the single colour fixed for the season and is strewn with little razor-like clouds, there will be rain on the same day; similarly, one that is yellow produces rain the same day if the sun shines fiercely.'

'When a planet and a star are enclosed within the halo round the moon there will be rain within three days.'

'A rainbow seen in the east when there is no rain, produces rain and *vice versa*; and in the west it always indicates rain.'

'When a mock-sun appears to the north of the sun, it gives rain; to the south a strong wind.'

Again as regards forecast for the coming year: 'The symptoms of pregnancy are to be detected when the moon transits *Purvashadha* commencing from the first day of *Margasira.*'

'The fœtus formed during the moon's stay in a particular asterism will be born 195 (solar) days hence, the moon standing again in the same asterism according to the laws of her revolution.'

'The fœtus formed in the bright half of the month will come out in the dark half and *vice versa*; and those formed in the daytime will come out at night and *vice versa,* and those which are formed at the dawn, in the evening and *vice versa.*

'The happy tokens in the month of *Margasira* and *Pushya* are a red glow of the horizon at dawn and evening, clouds with halos, not severe cold in *Margasira* and not too thick frost in *Pushya*; in *Magha* a strong wind, the sun and moon dim by mist, severe cold, and the sun rising or setting with clouds; in the month of *Phalguna,* a rough and violent gale, glossy floating banks of clouds, an incomplete halo round the sun or the moon and the sun russet or red; in the month of *Chaitra,* the fœtuses forming among wind, clouds, rain, and halos are good augury;

and in the months of *Vaisakha,* such as are attended with clouds, wind and rain, lightning and thunder are favourable.'

'An embryo that is formed in *Sathabhishak, Aslesha, Aridra, Swati* or *Magha,* proves fertile and develops (or rains) for many days.'—(*From the English translation by Pundita Bhushana V. Subramanya Sastri.*)

It must be pointed out that Varahamihira contemplates a day-to-day and hour-to-hour watching of the skies and every year, for a reliable forecast—a proceeding which cannot be improved upon even in modern times. For that reason at least these observations deserve study with respect and understanding.

The Barometer as a Weather Indicator.—The barometer, as is well known, indicates the atmospheric pressure in the place in which it may be installed, in the same way as the thermometer indicates the temperature. As a lower reading in the barometer means that the atmospheric pressure at the place is falling and as such a fall in the pressure indicates that a disturbance in the weather may be expected, the instrument is made use of for this purpose, popularly. Many makes of barometers accordingly have a dial on which pressure variation or drop is expressed in terms of the change that may be expected, such as 'fair', 'much rain', 'stormy', etc. Even in countries where they have been in regular use, these indications are not always correct; but in India they are quite inapplicable, because there are many kinds of variations, both diurnal and seasonal, to be allowed for, besides the fact that some of these are large enough compared with the fall that may presage any violent change in the weather. Even in places situated at sea-level, these dial warnings do not apply; in the case of a plateau like Mysore and of all hill stations, they may be positively misleading. Without a proper study of a large number of figures spread over a long period, the readings will not be of much use ordinarily. Nevertheless, if it is found that the barometer is steadily falling for one or more days, or that the fall is rapid and abnormal, then it may be taken as an indication of an approaching high wind, storm or rain or both wind and rain.

The Weather Chart.—An accurate figure for the barometric pressures for all the meteorological stations in the country, with all the necessary corrections made, is given in the Weather Charts published by this department. It may perhaps be explained, that in these charts places having the same pressure are connected by a line which is called an 'isobar'. In the Indian charts, there is an 'isobar' for every pressure difference of ·05", so that a station lying on any one isobar has a pressure which differs by ·05", from those lying on the next isobar, above or below it. If these isobars are very wide apart, then the 'gradient' is small, *i.e.,* the fall is not sharp or steep. If, on the other hand, the isobars are very near to each other or divided by a short distance then the 'gradient' is high or steep, these terms being similar to those used in reference to contour maps, showing the level

or surface elevations in the country. If a region in the chart is surrounded by isobars of low pressure, then it is called a 'barometric depression' (or merely a 'depression' in the language of the charts) or low pressure region. As the air rushes from a high pressure region to one of low pressure, a 'depression' is one towards which the wind rushes from a high pressure region. If at the depression the gradients are unusually or very steep, *i.e.,* if the isobars are very near to each other, then a high wind, storm accompanied by rain or a cyclone may occur in that region. The steeper the gradient or intensity of 'depression', the greater the disturbance and the more violent is the storm, rain or cyclone. Conversely, the lower the intensity the less is the degree of unsettlement. A 'depression' may lie over a region for a prolonged period of a day or more or move forward quickly, carrying the storm or cyclone along the regions in its track.

Cyclonic weather generally prevails over the Bay of Bengal and especially along the Coromandel Coast during the season of the N.-E. Monsoon ; these annual visitations have also a more or less regular and definite track, generally along the coast of the Northern Circars and of the districts of Chingleput and South Arcot. Farmers in these regions are therefore to some extent prepared for the contingency and all sugarcane fields in these regions, for instance, are regularly propped up with strong upright supports, so as to prevent them from being blown down and damaged.

Cycles and Long-range Seasonal Forecasts.—The Hindus reckon their calendar in cycles of sixty years, each year bearing a special name such as *Prabhava* the first year beginning the cycle and *Aks'haya* the last one or sixtieth, closing the cycle. The belief is that the conditions influencing the agriculture, health and well-being of humanity in any particular manner which prevail in any particular year, will recur in the year of the same name in the next cycle, *i.e.,* sixty years after. In a general way the prospects of each year are more or less defined and described and are therefore foretold in the beginning of the year itself. This may be called the 'Long-range' forecast as distinguished from the 'Short-range' or day-to-day, forecasts of the weather bulletins and *slokas* described above. It corresponds in a way to the forecast of the year's monsoon prospects, which weather experts calculate beforehand and express as a percentage of the normal.

Shorter Cycles.—Within this sixty-year cycle itself there are said to exist cycles of seven-year periods when also conditions to a certain extent recur. A somewhat corresponding cycle or recurrence is popularly associated with the appearance of sunspots, which are said to recur in cycles of seven- or eleven-year periods, influencing the rainfall and other seasonal conditions in a manner which can be foretold from those of the previous occurrence of sunspots seven or eleven years before.

Regularity of Natural Phenomena.—It cannot be stated what amount of truth there may be in these beliefs. *Prima facie* at any rate, there is much to be said in their favour. There is nothing so certain and absolutely beyond doubt in this world as the recurrence of natural phenomena in a most regular manner, and it is a commonplace remark that nothing is more certain than that the sun will rise in the east on the morrow. All planetary movements obey the law and it is only reasonable to expect that the conditions for which they are responsible also recur in the same way and are, or should be, therefore capable of being predicted much in advance. This is mentioned only to stress the fact that these matters should not be lightly brushed aside but should receive careful and sympathetic study.

CHAPTER II

SOILS

GENERAL

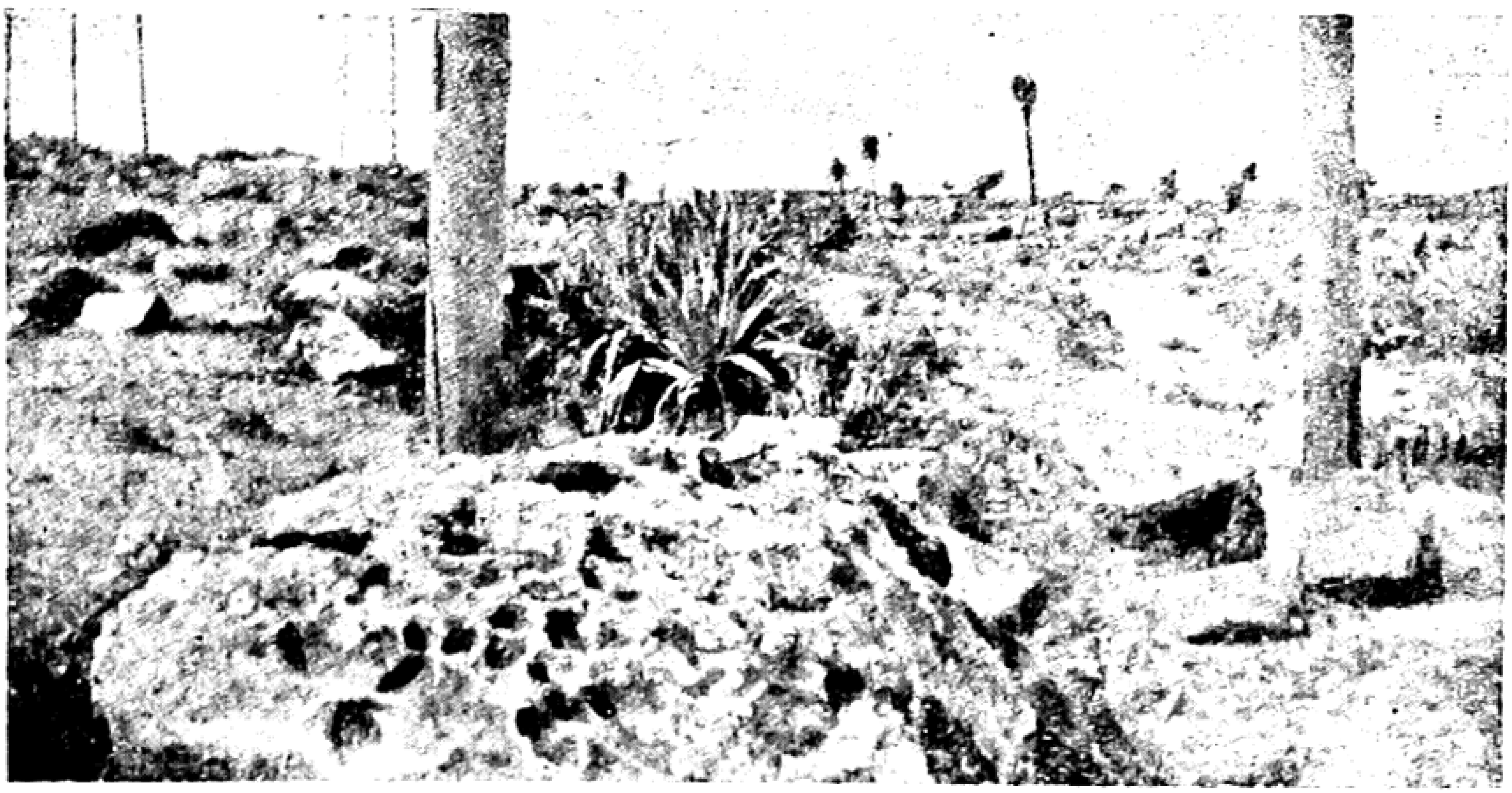
THE soil is the cap or covering on the solid crust of the earth's land mass made up of broken down rock material of varying degrees of fineness, and changed in varying degrees from the parent rocks by the action of different agencies, such that the growth of vegetation is made possible. Though compared with the depth of the underlying rocks, the layer of soil is almost negligible, still it forms not only the foundation of agriculture which yields to human effort but also a kind of limitless wealth from which mankind derives its life and sustenance. Carefully husbanded and worked, it is an asset that can be passed on to countless generations almost intact, forming a most precious and all-important legacy. The soil is truly "mother earth" from which not only is the food of all living creatures on the land derived but also the innumerable products of the vegetable kingdom which are indispensable for the arts and industries of civilised mankind. "Agriculture" which literally means the "cultivation of the *field*" epitomises the role of the soil in the production of food and raw products.

FUNCTIONS OF THE SOIL

The soil is the natural storehouse of the plant food requirements of crops and many soils can, without any manuring or addition of extraneous plant foods, yield moderately good crops almost without end. The soil is the medium through which alone crops can take up their all-important requirement, *viz.,* water, and all the supply required has to be given only through the soil. The soil is the medium too in which growing plants find their bracing and anchorage through their root system and are enabled to maintain their firm position both of roots and above ground parts, which are thus able to perform their respective functions normally. It is the seat of many chemical changes, in the presence of air and water, the total effect of which is the setting free of more plant foods and the neutralisation of the harmful products. It is the home too of a teeming bacterial life, which together with other forms of life are all engaged in making the soil richer and more sanitary to the spread and functioning of the root system.

It is true that crops can be grown without soil and in a sort of "water culture", and that some striking results have been produced and that the method has been dignified by the special name of "hydroponics". While it shows what it may be possible to accomplish, it need hardly be pointed out that the soils available for crop raising over the globe will never shrink so much as to force mankind to resort to "hydroponics" for its means of sustenance. As a

Weathering and decay of rocks—The result of centuries of weathering, typical of the disintegration into boulders, often of peculiar shape, undergone by gneissic rocks. *Photo by Author*



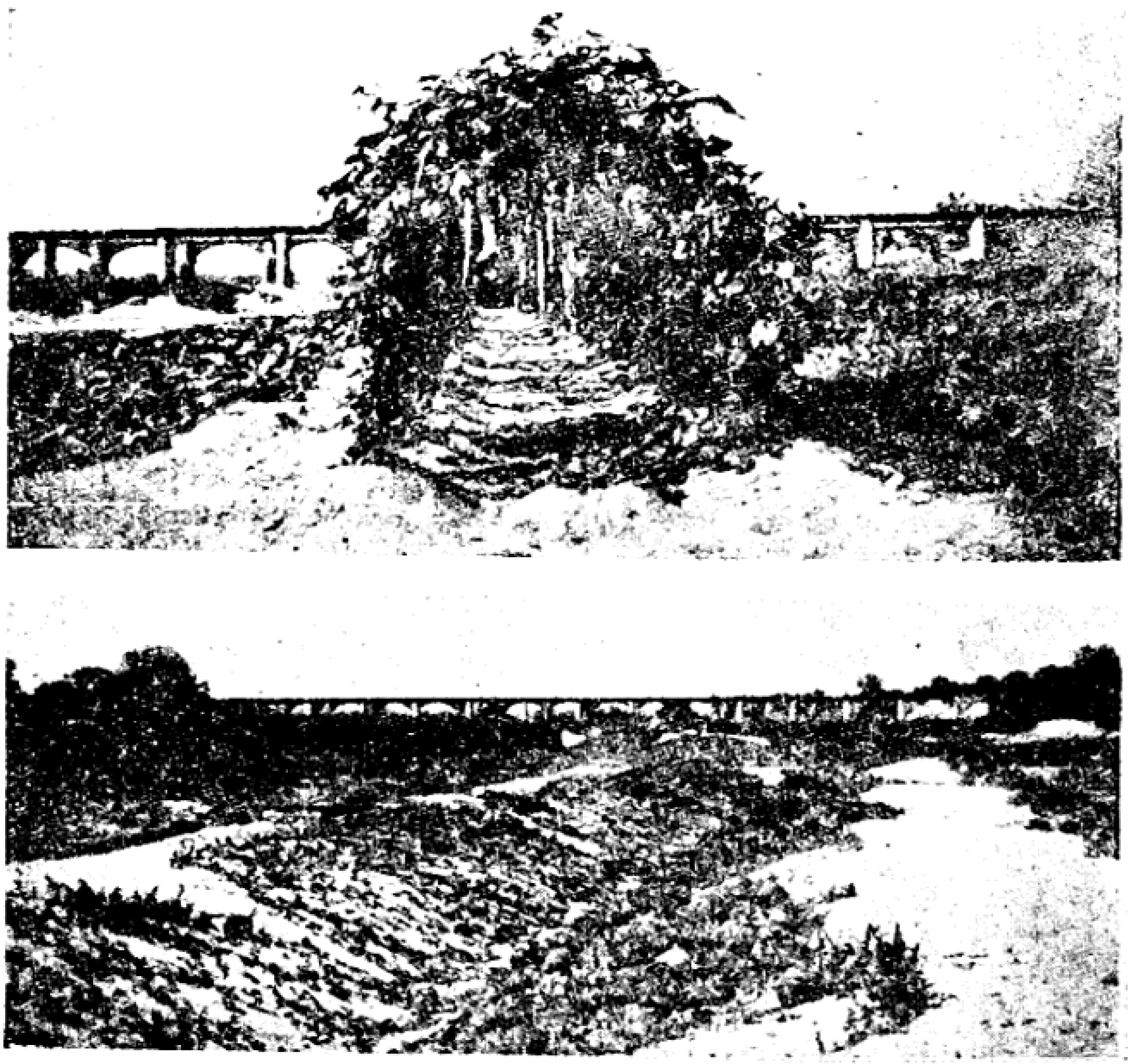
Weathering and decay of rocks—A boulder showing how soft portions in the rock decay and are washed away, leaving "pock marks" on the face of the rock. Note also the white dried up remains of the lichen growth of the previous season encrusting parts of the boulder. *Photo by Author*

a *b* *c*

SOIL MASSES OVERLYING

(*a*) Unchanged sheet rock, (*b*) rock splitting with numerous cracks, and tree roots helping in the process, (*c*) soft unweathered white clay.

Photo by Author



Cultivation in sand: Great crops of melons and many vegetables are raised in the riverbeds of pure sand, of certain rivers, as soon as the floods abate. Two views of riverbed cultivation in bed of the Tunga river, Mysore; upper picture shows snakegourds (*Trichosanthes. anguina,* Linn.) grown on archways; lower picture shows water-melons (*Citrullus vulgaris*, Schrad.) on mounds of sand.

Photo by Author

practical measure the method may find some scope in the case of the little rocky islands where light-houses or radio stations may be located and to which soil has to be brought in for raising the vegetable, fruit and flower crops for the use of the few lonely men and women who form the operating staff on such stations.

It must be pointed out, however, that the term "hydroponics" is used to include also a form of pot-culture in which the culture medium is not water but is either clean sand or an "aggregate", which is made up of coarse material like gravel, cinders, granite or other rock fragments together with sand which are filled into a shallow trough or built up bed, to a depth of about 6", somewhat in the manner of a flower pot. In the Hydroponics Research Centre at Kalimpong, Darjeeling, the "aggregate" or coarse material used comprises gravel, crushed rock, cinders, or granite chips of between $\frac{3}{8}$–$\frac{1}{4}$" grade. To the rock fragments the residual dust and sand are also added, in the proportion of about 1 part of the latter to 5 of the former. It will be thus seen that although in the water-culture method of hydroponics the growing medium is the nutrient solution itself (very largely diluted, of course), in the sand-culture or "aggregate" culture it is some kind of soil-like material, which is used. The latter does not possess the character of a soil as a container of plant nutrients in the manner of a natural soil but retains nevertheless its character as a home for the roots to spread in, and furnishes the bracing and anchorage as well. The essential feature of the method is that the plant nutrients are supplied "ready-made" to the crop in the form of a solution, in frequent small doses, without its having to abstract them from the soil as in ordinary cultivation. The merit evidently is the possibility for the crop to benefit fully from the nutrients added, without any of the latter being neutralised or fixed and made unavailable by interaction with the constituents of ordinary soils.

How Soils are Formed

The hard rocky crust of the earth being the material from which the soil is primarily derived, the first change that the parent rock has to undergo is a breaking down and crumbling and a decay into the loose aggregate of particles which is the characteristic physical condition of all soils. The agencies which bring about these changes are: (1) physical or mechanical, (2) chemical, and (3) biological.

1. *Physical or Mechanical Agencies.*—(*a*) *Heat and Cold.*—The effect of temperature and of the diurnal and seasonal variations therein result in a loosening of the texture of the rocks in a marked manner. The loosening of hard gneissic rocks by burning brushwood on the surface which has the result of breaking the rock asunder at the bedding planes and facilitating the separation of large slabs or sheets of the rock is a familiar example of the way in which such a high temperature acts upon the rock. In a less intense form but

producing the same result by prolonged action, high atmospheric temperatures bring about the same kind of result. Just as heat is made use of in India in this way, cold is made use of in cold countries. For instance, it is the practice in Wales, we are told, to raise stone slabs by forcing water in between the bedding planes, which on freezing has enough force to heave the slabs apart.

In addition to their action upon the rocks as a whole in this manner, both heat and cold act upon the individual minerals of which the rocks are made up and as they expand and contract unequally in the process, a loosening of the minerals in their matrix takes place leading to a gradual crumbling of the rock.

(*b*) *Water.*—The freezing of water whether as a thin film or in larger quantities as in cracks, fissures or bedding planes produces a shattering action by its expansive force and the cumulative effect of such action through the ages is most destructive to the structure of the rocks. Water in motion is even more destructive; the abrading force of a torrent, waterfall or river in flood, rushing through a narrow breach upon the rocky beds and sides is enormous. Hard granite can be cut through as though with rock boring or cutting machinery. Rocks are torn into boulders which are rolled together and against the sides and bottom of gorges wearing each other smooth with the formation of the finest mud. Even in ordinary streams, the action of running water wears down hard fragments of stones into smooth "water-worn" pebbles. Water in motion is probably the most powerful agent concerned in wearing down hard rock into stones, gravel, sand and silt, and even into impalpable mud.

In past geologic ages frozen water or ice has moved along the face of the earth like great rivers or 'glaciers', a process which takes place even to-day in Alpine and Himalayan regions, which carry before them boulders and rocky fragments, large and small, abrading the rocky beds and sides of the valleys of the route with enormous force and reducing them to smaller and smaller fragments.

(*c*) *Winds.*—Just as flowing water wears away rocks, so also do strong winds laden with sand cut into and wear away rocky hills across their track both normally and during violent storms; the softer strata or beds wear out more readily and their unequal wearing further weakens their structure leading to their breaking down into heaps of loose rock.

2. *Chemical Agencies.*—The chemical agencies, also referred to as "weathering agents", bring about changes in the composition of the minerals composing the rocks, as the result of which they separate and loosen themselves; portions are dissolved out as they now become partly soluble in water and are removed by solution or by mere mechanical washing out and the rock loses its character as a hard compact material and crumbles down. These chemical agents are: (*a*) the atmospheric air, the active agents being oxygen, carbonic acid, and to a small extent nitric acid, formed during thunder-

storms and brought down by the rain, and (*b*) water itself both by its dissolving effect and by chemical hydration.

By the process of oxidation the ferrous iron of many minerals becomes converted into the ferric form, producing an intensification of the red colour as an outward indication and with the separation of the oxides of iron from the combination; the yellowish iron pyrites in many rocks become oxidised into the higher oxide and sulphates, both of which lead to the disintegration of the rock in which they form a part. Carbonic acid especially in the presence of water acts slowly upon carbonate of lime bringing the carbonate into solution; likewise in the hard silicates of potassium, sodium, with iron, alumina, lime or magnesia of which all rocks are largely composed, the alkalies are acted upon with the formation of carbonates, which are washed out, being soluble in water, leaving the residual material as a soft broken down debris, composed of pure clay (kaolin) with unweathered or partially weathered components. The name 'kaolinisation' is also applied to this kind of weathering.

Water itself exerts its solvent action especially upon the minerals containing alkalies slowly but steadily and forms a kind of mild corroding agent. Some of the compounds undergo a slow process of hydration and consequent chemical change; oxides of iron may be converted into hydrated oxides and loosened out, and great masses of iron ores of different kinds are often found in the form of such soft material of hydrated oxides of iron. Water is mainly concerned in the formation of calcium hydrogen carbonate, in the form of which much of the hard limestone rocks undergo softening and solution.

During thunderstorms and flashes of lightning, the discharge of powerful electric energy in the atmosphere brings about a combination of the nitrogen of the air with the oxygen and the formation of oxides of nitrogen. Brought down by the rain in solution as nitrous and nitric acids, these are able to exert a solvent action on the minerals in rocks, especially the easily soluble ones like the carbonate of lime. It has been estimated that in tropical regions of heavy rainfall about 30 to 35 lb. of nitric acid are added per acre annually.

3. *Biological Agencies.*—Not a little of decay in rocks is brought about by the growth of vegetation on the surface and in among the cracks. Even on the bare surface of rocks many kinds of lichens and moss and such low forms of vegetation are capable of growing and in many such rocks circular patches of corroded surface can be made out beneath this plant cover, both during growth and more conspicuously after they die down. On some rocks there are lichens of certain kinds which almost cover the surface in little rosettes and which are collected for the sake of the medicinal value they are believed to possess. Vegetable matter during decay also corrodes the rock, a weak humic acid adding to the effect of the plant during growth. Root secretions by the growing plant are mildly acid

or at least such as to exert a slightly solvent action on the rock surface. Higher plants send down their roots into the minutest crack and can split the rock asunder by the growth of their roots, while the larger trees in such circumstances can work great havoc in this way. The destruction of many precious ancient monuments by tree roots is well known. Plants are able to take advantage of the slightest foothold in the form of a crack or a depression, in which some soil can be found and indeed even where none can be found as in the case of the lichens.

The action of earthworms in the formation of soils is also noteworthy, although the action gains prominence more after the decomposition of rocks and their reduction into finer particles has taken place. Earthworms pass through their bodies in the aggregate very large quantities of earth which is ground finer in the process and is ejected after the worms have abstracted the organic matter in the material for their own nourishment. These earthworm casts which are ejected on the top soil therefore form an addition of finer particles to the soil and they have to be regarded therefore as a soil-forming agency. It is a classical observation of Darwin quoted in this connection, that in the course of 50 years the whole of the soil on certain pastures to a depth of 10" is worked through in this way by earthworms and that the weight of such mass over an acre of surface would amount to over 2,000,000 lb. of soil.

From the point of view of soil fertility it has been found that earthworms greatly enrich the top soil on which they may be spread, so much so that the culture of the earthworm has been resorted to as a form of manuring. Analyses show that such soils contain a large accumulation of lime, that the mineral plant foods are in a more available condition and that the organic matter content is greatly increased.

In tropical countries the action of white-ants (termites) is responsible for even greater amounts of soil formation of this kind. These ants are ubiquitous and their nests and burrows both below and above ground are made up of well-ground up soil, while the dead remains of their innumerable colonies and their so-called 'fungus gardens' bring about much enrichment of the soil, and the aeration and oxidation in great masses of soil both above ground and below.

The various agencies of rock decay or disintegration act not merely singly but concurrently, one leading to or opening the door for another and to a progressive intensification of the work. Thus a weathered soil layer may be removed by water or wind and a further layer exposed, or crack or fissure produced by one agency may let in water or plant roots and intensify the change and so on.

Sedentary and Transported Soils

Soils are sometimes classified as Sedentary and Transported.

(*a*) *Sedentary Soils.*—The above agencies of various kinds bring about the primary change of the reduction of the hard rock masses

into the particles of which soils are composed. These products of disintegration, decay or abrading the rock fragments which become the basis in the formation of the soil may be left *in situ,* that is, on the rock face itself on which it was formed and the changes progressively took place and give rise to what are called *Sedentary* soils.

(*b*) *Transported Soils.*—More largely, however, by the action of running water, wind, etc., as already explained, the finer materials formed are transported from the parent rock or place of formation to far distant places and deposited in various places along their course. In the process of such deposition the particles undergo a certain amount of sorting out in respect of their texture, the coarse particles are the first to be deposited as the flow slackens, and the less coarse grades further down the river, until when the water becomes still only the finest material remains and settles into a fine clayey deposit. Alternation in the velocity of the flow gives rise to deposits in layers of fine and coarse particles, alternating one above the other. Such a feature is characteristic of deposits due to running water or *alluvial* deposits or soils. Similar deposits may form in lake bottoms, estuaries and in the sea bottom itself, which may get uncovered owing to the drying up, or receding of the waters, or due to geological agencies.

Glacial deposits are also formed of transported material and will contain a large admixture of coarse fragments along with the soil, bearing often the scored markings resulting from the abrasion during the flow of the glacier over or between rocks.

Deposits also result from materials transported by the wind, and many sand-dunes consist of such wind-borne materials, while in the famous 'dust bowl' of the U.S.A. (the name given to a portion of the States of Texas and Arizona) hundreds of square miles of country are subject to the shifting of the soil and denudation in one region and deposit in another. In Mysore on the banks of the Cauvery river at Talakad can be seen some remarkable sand-dunes, which have covered up all the ancient temples of the town and are threatening the town itself. These dunes are due to the sand blown along with the S.-W. Monsoon winds from the opposite sides of the bend of the river, which has been going on for centuries. Many such ancient cities and monuments have been buried under wind-borne sand in different parts of the world and even now such sand-laden winds are a menace to cropped land lying in their track. Where whirlwinds prevail, the fine soil is churned up and carried away by the whirling columns exposing the land 'pavement' below the soil. Volcanic ash during an eruption may thus also be carried long distances by the wind and deposited as a rich soil far away, constituting in a sense wind-borne soils.

To soils of all these types the general name 'transported' soils is applied, as distinguished from 'sedentary' soils. The wind deposits are sometimes given the special name of 'Aeolean' soils.

THE DEVELOPMENT OF THE SOIL

The next stage in the formation of soils is the slow development of the soil as a fit medium for the growth of crops, by changes which take place either after or simultaneously with the various processes described above. The changes which make the soil what it is in texture, composition, bacterial content, etc., in varying degrees belong to this second class. These comprise two different kinds, *viz.,* (1) the slow accretion of organic material on the surface by living vegetation or its dead remains, and (2) the loss of material by leaching or solution in the top layer of the soil and the infiltration into the lower layer, or even out of the soil mass altogether, through surface and underground drainage.

The addition of vegetable matter may accrue to the surface and to some little depth below the surface depending upon the nature of the vegetation and its root system. A mere grass cover may be all that results or great masses of fallen leaves may cover the ground in a thick layer. Old vegetation may perish and new vegetation spring up, all leading to an accumulation of organic matter through many years. If the climate is cold or humid, these may give rise to deposits of peaty material, but in the tropical warm climate the material will decompose rapidly, but much organic matter will still be left in the soil, the decay not keeping pace with the accession of new material. It is reported that if accumulation in humid climates of fallen leaves should be as great as in the tropical forests, then a layer of peaty humus many yards thick will result, whereas in the tropical climates this seldom goes above 8" at the most. The colour of the soil changes on account of this admixture and assumes a dark more or less reddish tint in contrast with the lighter colour below. The mild acidity of the humus or decomposing material also dissolves and further improves the soil in its soluble constituents. The exposed surface and the looseness produced by the soil favours aeration a great deal, on account of which oxidation and weathering changes proceed to a greater extent than in the lower layers leading to a further growth of the soil. It will be seen that this set of changes is in the nature of a large addition to the soil in different ways.

The second set of changes consists in the action of rainwater on the top soil, the water both by itself and aided by the carbonic acid of the air and the acids derived from the decaying organic material; as the result, considerable soluble material is dissolved out and carried down into the lower layers and the disintegration of the rock below the highly weathered top surface is also promoted to some extent. If the region is one of heavy rainfall these may be carried to great depths or more often leave the soil altogether along the surface or underground into streams or rivers. In arid or semi-arid climates, the dissolved material may deposit itself in the soil itself not far below the surface and may lead to the formation of

concretions, nodules or 'hard pan', the depth at which these form depending principally on the nature of the rainfall. Some of the soil itself may be mechanically carried down into and between the cracks and joints in the rock below. In the final result, the lower layers become richer and the top layer poorer by this process, this change being greater in proportion to the rainfall. A soil out of which soluble and other portions have been lost in this manner, is sometimes spoken of as a 'residual' soil.

Both the two processes are confined to only very small depths, the first to the top alone and the second affecting both top and the lower layer in addition. Below this neither change can reach and the parent rock remains intact.

Soils and Subsoils

It is usual to distinguish the top soil as the 'soil' which is agriculturally the subject of various treatments to make it a fit medium for growing crops and which forms the most favourable zone for the spread of the roots of all ordinary crops, from the layer below it or the "subsoil". When a pit or trench is dug it will generally be seen that the face of the exposed surface is by no means uniform in appearance; a top layer which may vary in depth according to circumstances is different sharply in colour from the layer or layers down below. The top layer down to the point or level where the change of colour begins is called the "soil" and the layer down below the "subsoil". If the soil mass is fairly uniform in colour to a considerable depth then a conventional depth of about 8″, being the maximum depth of ploughing or a depth of even 1′ for chemical analytical purposes is taken as the soil and the second foot as the subsoil. If the soil is not uniform then 'soil' is only up to the line where the change of colour or mechanical composition begins and lower down is the subsoil.

The soil usually differs from the subsoil in being of a darker colour owing to the presence of organic matter from the yearly additions of manure and the remains of stubble and weeds and of a leaf cover of fallen leaves in jungle soils; in the case of the red soil it may happen that the subsoil is a deeper red than the surface soil as likewise in the ordinary light brown or grey soils. Mechanically the soils may have a lesser content of finer particles or clay, as these are carried down by the yearly rainfall into the subsoil. In fact in certain situations the loss of finer particles may be so great, generally on account of the nature of the ground, as to make the soil appear more and more coarse as the years go by. Chemically they may have a higher nitrogen content than the subsoil on account of organic matter accumulations, while in respect of the mineral constituents the latter may be richer, principally because there is a gradual infiltration of these from the top into the lower layer. The subsoil is indeed looked upon as a good reserve, which

may be tapped by gradually increasing the depth of ploughing. Much caution is however required in so doing, as the subsoil is likely to be raw or unweathered, as the oxidation and aeration is poorer in them than in the top soil and there is the danger of bringing up this unweathered soil to the top where it may prove harmful, at least until it has weathered sufficiently. The unweathered subsoil is easily made out by the light creamy or yellowish tint peculiar to this condition. This may be so only in extreme cases, but ordinarily it may not be so easy to make out and as appearances may be deceptive, it is always safe especially in the case of soils which have been in cultivation by the use of a particular type of ploughs, not to increase the depth except very gradually. The differences in chemical composition between soils and their subsoils will be seen from the instances given in the table appended to the next chapter.

. Soils are often underlaid within small depths by rock, gravel, concretions of different kinds, sands, stiff clay 'pans', the more soil-like among them may be even classed as subsoils. Agriculturally all these have a bearing on the value and suitability of the soil. Rocks of different kinds, hard sheet rock like granite or rocks in various stages of decomposition like schists, flat or slanting or vertical in disposition, trap rocks, shales, etc., are often met with in this manner. The soil on the top may be sometimes very shallow from 6" to 1' and the more shallow they are the less valuable they become. The black cotton soils which are deep and uniform generally are sometimes only a few inches in depth overlying such rocks. Instead of rocks of this kind limestone concretions, nodular or finger-shaped may occur at short depths but only irregularly distributed and do not seriously affect the value of the soil on top, the case being different of course where there is a regular deposit. In red soils a frequent underlying material is of concretions of laterite pebbles, both large and small, and in the laterite tracts proper, sheet laterite rock is found very near to the surface, making the soils practically valueless. Gravels and coarse sands as subsoils confer the advantage of good drainage, although they may be poor as a reserve of plant foods. In many situations notably in low lying land and in tank-irrigated soils, the subsoil may be formed of stiff clay, often insufficiently weathered and in the case of red laterite soils a stiff ferruginous clay 'pan' or hard layer may be formed within a short depth. Where mouldboard ploughs are used as a general practice, the plough 'pan' of the same kind may be formed right under the sole of the plough. These hard subsoils impede drainage, restrict the root range of the crops and prove harmful to crops. In arid regions (in the U.S.A.) such hard pans some feet in thickness are common and they are broken through by shattering with a charge of dynamite, before cropping (especially the planting of fruit trees) is attempted. Ordinarily a subsoil plough

or deep digging is enough to break them and render them harmless.

Both subsoils proper and these underlying layers of different kinds considerably affect the agricultural value of the soils and have to be examined and specified in any description of the soils. Soils are nowadays described in their profiles and in different 'horizons' therein, and this method gives a better picture than that of referring to them as soils and subsoils in the usual or old way.

According to this system, the name 'horizon A' is given to the top layer of the soil from which continuous loss takes place by the leaching of soluble constituents into the lower layers as already described. The name 'horizon B' is applied to the lower layer or zone which receives a steady increment of such leached ingredients from the top layer and becomes increasingly enriched. The name 'horizon C' is applied to the zone or layer which remains practically unaffected by such changes, being far removed from the operation of these factors.

Physical Characteristics of Soils: Clays, Loams and Sand

Many of the distinguishing characteristics of soils of different kinds depend upon their physical composition. In familiar language, the terms sandy, loamy and clayey, with several gradations therein, are descriptive of this condition, and indicate the nature and suitability of the soil agriculturally and the manner in which each class behaves under different conditions or has to be treated under cultivation. The texture depends upon the proportion in which the particles of different sizes which go to form the soil are present in it. The fineness or size of these particles is fixed somewhat conventionally and a mechanical analysis of the soil gives the proportions of the different grades. Before going into the classification according to these rather elaborate standards, the commonly understood classes may be briefly referred to.

At one extreme are the soils which may be called stony or gravelly, which have a large admixture of large fragments of stone, gravel, pebbles, etc.; these are poor soils, hard on tillage implements and plough bullocks, and generally found on upland situations. Strange as it may seem, in dry-farmed fields there is a greater chance of moisture being retained in such soils than in the finer soils usually classed as very much better soils. The fragments of stone appear to act as a kind of 'mulch' on the soil. With the exception of this one feature they can be classed among the low grade soils.

The next in respect of coarseness are the *sands or sandy soils.* Soils which are made up either solely or mostly of sand are rearly used for raising crops, but they are capable of such use, provided water and manure are available in plenty. Under these conditions and under the pressure of extreme need, very remarkable instances

of cultivation in sand are met with. In South India striking instances are furnished by the cultivation of ragi, chillies and many garden crops in the sand-dunes of the Krishna District, of garden crops on Rameshwaram island, of tobacco and vegetables on the west coast in South Canara, and of water melons and vegetables on the sandy riverbed of the Tunga and Tungabhadra rivers. Except where the sand is subject to shifting and blowing, human ingenuity is able to put even these sands to profitable crop production.

Soils containing more than 60% of sand are classified as sandy soils. Both sands and sandy soils are very easy of tillage, the former needing hardly any tillage worth mentioning. They are easily drained and their facility in this respect is really a drawback, as they let the water through too readily, necessitating frequent irrigation or hand watering. Great care has to be taken to see that water is not lost through irrigation channels in transit and these latter may have to be lined with cement or only pipes of metal or glazed earthenware used. If they are underlaid by stiff and less permeable layer, then they become easily water-logged. Evaporation from the surface is slow and so is capillary rise. Sandy soils are poor in respect of plant foods and require heavy manuring and in frequent doses. On account of this great need for water and manure sandy soils are described as 'hungry' soils. Cattle and sheep manure, green manuring and the addition of tank silt and clay, will bring about great improvement in the retentive capacity of these soils.

The next in order are the *loams or loamy soils.* Agriculturally these are the soils best adapted on the whole for cultivation. They are intermediate between sandy soils and clayey soils. Soils whose sandy component lies between 30 and 60% are classed as loamy soils. In drainage, retentiveness of moisture and in moisture-holding capacity they are intermediate between sandy soils and clayey soils. They are suited to practically every kind of crop and all the various tillage operations are generally best adapted to this class of soil and result in producing in these the ideal kind of tilth aimed at by them.

The next in order are the *clay soils and the clays.* In these the sand component goes below 30% and the clay goes up between 70 and 85%, when it is termed a clayey loam; if the clay exceeds this maximum then the soil is a stiff clay. Clayey soils are difficult to till and require much skill in handling. When moist they are exceedingly sticky and ploughing or other tillage in that condition will reduce them into a pasty mass. When they are dry, they become very hard and difficult to break. As they dry they shrink in volume and numerous surface cracks develop. They are difficult to drain as the water cannot pass through them easily on account of the fineness of the particles composing them. They have a high water-holding capacity and are also very retentive of moisture. They are generally very fertile soils, in respect of plant food contents, though

they will need physical improvement before crops can derive this advantage in full.

The difficulty of tillage is their chief drawback and this increases as the soils become more and more clayey. The addition of sand, lime or limestone, coarse bulky organic manure, will all improve their physical condition.

Many of the properties of typical clay soils are due to their content of very finest fraction of the soil particles, which behaves like colloids and to which the name *'soil colloids'* is applied. The colloids form the cementing material binding the particles of soil together and giving it the cohesion, stickiness and plasticity, when present as a large percentage as it does in typical clays. Chemically and from the point of view of plant nutrition the most important among these properties is its power to absorb and fix many of the chief plant foods. Thus the nitrogen applied as organic matter and that in the shape of ammonia, free or combined as in the ammonium salts applied as manure, becomes fixed in the soil, that is to say, these do not pass out of the soil in the drainage waters. Similarly phosphoric acid and potash are also fixed almost completely. On the other hand, nitrates, chlorides, sulphates usually in the form of their calcium and sodium salts, are passed through practically completely into the drainage water.

Other Factors Influencing Physical Condition : Humus and Lime

The physical condition of the soil, produced by the variation in the proportion of the different sizes of the particles composing it described above, on which soils may be classified as stony or gravelly, sands, sandy loam, clayey loam and clayey and stiff clays, is also much influenced by some other factors which are (1) humus or organic matter and (2) lime.

Humus.—The partially decomposed remains of organic matter (vegetable or animal) constitute the humus in the soil. In humid regions and in low lying situations with partial exclusion of air the carbonaceous materials are only imperfectly oxidised and products like marsh gas may be formed instead of the final product, carbon dioxide. In arid regions and in tropical climates and in open high lying situations the organic matter undergoes decomposition rather rapidly, the carbon being completely oxidised into the final product, carbonic acid. A more or less semi-decomposed organic matter or humus is formed as the result and accrues to the soil; the actual amount and nature of the humus, depending upon the rapidity of oxidation.

The presence of humus gives the soil its distinctive character as distinguished from mere ground-up rock; it helps to give the tilled soil its peculiar 'crumb' structure; it enables the soil to absorb and retain moisture; it induces bacterial action making the plant

foods in the soil more available, gives a loose soil some coherence and in a clay soil prevents the tendency to become pasty. Tillage and other operations should be such as not to hasten the decomposition or reduce the humus content unduly but to carefully husband it and increase its content in the soil.

Humus is sometimes divided into acid, neutral and alkaline. The acid humus results when there is not enough lime in the soil to neutralise the acids formed during the process of humus formation and the two latter when the lime is sufficient to neutralise them or is left over in excess, respectively.

Lime.—The presence of lime in soils confers very important properties, both physical and chemical. Reference may be made here only to its effect on the physical condition of the soil. Lime largely ameliorates a clay soil by its flocculating effect; clay in suspension is difficult and slow in setting, but can be made to readily settle by the addition of a little lime which immediately flocculates or makes the fine particles cohere into larger ones and sink readily to the bottom. The same result obtains in the soil and the tendency to become stiff and pasty is largely overcome. It prevents the development of acidity in the soil which is a factor which favours the destruction of the tilth in the soil. It is very much due to the presence of adequate quantities of lime that soils can respond to tillage and assume the 'crumb' structure typical of good tilth. Lime as a component of soils is dealt with further on also (see chapter on Manures).

THE MECHANICAL ANALYSIS OF SOILS

In the classification of soils as sandy, loamy and clayey as described above, the basis is the size of the particles composing the soil. These sizes have been fixed by common consent or convention and the following table gives the sizes pertaining to each class:

Particles of diameter between	2 mm. and ·2 mm.	Coarse sand
,, ,, ,,	·2 mm. and ·02 mm.	Fine sand
,, ,, ,,	·02 mm. and ·002 mm.	Silt
,, ,, below	·002 mm.	Clay

The classification based upon the proportion of these particles is as below (U.S.A. system):

	Silt and clay (per cent.)	Clay (per cent.)
Sands ..	Less than 15	Less than 20
Loamy sands ..	15 to 20	,, 20
Sandy loams ..	20 to 50	,, 20
Loams and silt loams ..	over 50	,, 20
Clay loams ..		20 to 30
Clays ..		over 30

The actual methods of analysis are outside the scope of this book, but the principle on which they are based may be indicated. Two different methods of separating the particles of different sizes are followed. In the one the variation in velocity of flowing water

is made use of for the separation, which is analogous to what takes place in nature in the sorting of sand and clay in an alluvial soil. In this method the soil (after a suitable preliminary treatment) is passed through a series of pear-shaped vessels by a current of running water, whose velocity varies with the size of the vessel; the series is so arranged that the first one has the highest and the last one the lowest velocity, so that the heavier particles are deposited in the first and the lighter like silt and clay in the succeeding ones in order.

In the second method (which is now generally adopted) the principle of sedimentation is followed. The soil (after suitable preliminary treatment) is stirred up in water in tall cylinders and allowed to stand for a definite length of time, during which one or more groups of particles subside; the sediment is then subjected to the same process, the time however being varied, so that a further fraction is separated out. Repetitions with further variation of time bring about a further separation until the different groups are practically each of them pure to its size or range of sizes.

A simpler and somewhat rough and ready method is the use of sieves of different meshes, in which the soil may be rubbed up with water, and the grades separated, but this is obviously only a very approximate method and cannot separate the fractions finer than fine sand or coarse silt. The preliminary treatment referred to is for the purpose of preventing the clay particles from cohering and it helps in dispersing them. For this purpose the action of the humus and the lime is destroyed, the former by oxidation with hydrogen peroxide and the latter by dilute acid.

Heavy and Light Soils

In ordinary farming practice the sandy soils are referred to as 'light' soils, the sandy loams as 'light' loams and the clay soils as 'heavy' soils. The greater the sand component the 'lighter' is the soil and the greater the clay the 'heavier' it is called. These terms have no reference to the weight of the soils, as the terms ordinarily signify. As a matter of fact, a cubic foot of sand weighs very much more than a cubic foot of clay, the proportion being roughly as 100 to 80. As used in relation to soils in the above manner the terms have reference to the comparative ease of tillage, or the resistance which they offer against tillage implements; the clay or 'heavy' soil is much more difficult to plough and till than the light or sandy soils which are easy.

The actual weight of the soil is a very varying figure, depending upon its physical composition and its moisture content mainly. The weight of an acre of soil to a depth of 1′ may vary from 1 million to 5 million pounds. A figure which is taken as a rough approximation is 3,000,000 lb.

CROP CHARACTERS AND SOIL TYPES

The predominance of sand or clay is generally reflected in the character of the vegetation, the kind of crops best suited to each and the change that may be brought about in the same crop, when grown on the different types. As a general rule on account of the comparative poverty of sandy soils, vegetation on them is sparse, and the kinds are very hardy, thin and struggling. On the very sandy soils the vegetation is more of the creeping kinds, on account of the poor anchorage afforded by the sand for the roots. The root system in the lighter soils is deeper and more developed; root crops like potatoes, radish, sweet potatoes, etc., are more favoured by lighter soils than clay soils. Crops on light soils are somewhat earlier than on clayey soils; for example, in the case of sugarcane on clay soils the maturity of the cane is somewhat delayed. On the clayey soils growth is more luxuriant, the leaves and stems are larger and the quality of the produce somewhat coarse. Sugarcane grown on clayey soils gives a darker coloured jaggery while in lighter soils the juice is brighter and the jaggery hard and light in colour. Tobacco on the heavy soils is generally more coarse and large-leaved than on light soils. What is termed "quality" in other crops also, such as barley, rice and wheat, various fruits and vegetables esteemed for sweetness or flavour or other quality, the boiling quality of potatoes dhall, etc., are also to some extent influenced by the sand and clay proportion in soils. In general opinion and experience also the two types are considered favourable to different kinds of crops. The clay soils are favourable for rice, wheat, tur, Bengalgram, peas, beans, cabbages, plantains, turmeric and linseed. The loams of different kinds are more or less general purpose soils and are suited to practically all classes of crops, principally ragi, jowar, bajra, potatoes and many root crops, sugarcane, ginger and turmeric, gingelly and other oilseeds, jute, mustard, etc. The lighter loams are favourable for the millets and for ragi and jowar and bajra, cocoanuts, potatoes and other root crops.

Crops are also typical on the black cotton soils; these are jowar, cotton (of the Asiatic varieties), Italian millet, wheat, Bengalgram, linseed, all of which are grown more generally as dry crops.

THE COLOUR OF SOILS

The colour of soils is often some index of its quality. Ordinary arable soils are brown, deep brown, almost red, light coloured, ashy grey, and black either deep or light. The black and medium black soils are considered the best, the brown and the deep brown and red, the ashy grey and other very light coloured soils are put next in order successively. This is only broadly true and there may be many exceptions. Soils which are approximating to cream colour or yellowish or mottled greenish and bluish are highly unweathered and quite unsuitable. The tints are generally due to

poorly oxidised compounds of iron. Soils may be whitish with incrustation in patches, large or small, indicating the presence of injurious salts making them quite unsuitable for crops.

The black colour of soils is usually due to considerable humus or organic matter or to finely divided particles of black minerals derived from the parent rock. If a soil sample is heated, the presence of organic matter may be detected by the peculiar smell of ignited carbonaceous material; if the soil is mixed with soda and lime and then heated, even the presence of nitrogen can be detected by the smell of ammonia which is evolved on such heating. The humus itself can be removed by treating the soil with dilute ammonia or caustic soda and pouring off the solution, when the soil residue is bleached by the loss of the black colouring humus matter.

The black-coloured soils become very much heated under the humus having been dissolved by the alkali and then left as a black coating or deposit on the surface of the soil. This is one of the exceptional cases where the black colour is a danger warning. far from being an indication of fertility as in the case of ordinary black soils. In these black alkaline soils the colour is only a thin black coating and the soil below may not be black at all.

The black-coloured soils become very much heated under the hot sun and the light-coloured or ashy grey ones to a very much less degree. The black cotton soils become almost unbelievably hot in the summer afternoons, when it will be impossible to walk barefooted on such fields. The temperature on the black cotton soil has been found to reach 70° C. as a maximum as against 65° C. in the brown- or red-coloured soils. It is sometimes surmised that such desiccation of the soil during the prolonged summer is responsible for the great fertility of these soils.

On cropped land such a heating up is a great disadvantage as what is required is a more cooling effect. In black-coloured soils on a field scale this cannot be remedied; but in the case of pot plants or fruit trees irrigated in the 'basin' system, it may be possible to cover the surface with white cloth or paper, and keep out the great heating effect. The stems of trees are somtimes given a coat of whitewash or are covered with whitewashed gunny or cloth, especially against the western sun which is very severe and causes the stem to split or the bark to be scorched on that side.

The black colour of the black cotton soils cannot be put down to its organic matter content or humus, as this is too little to account for the colour. Moreover the residue left after the destruction of the organic matter with digestion with strong sulphuric acid (as for the determination of nitrogen by the Kjeldahl method) is still black in colour, showing that the colour is not due to organic matter. It is surmised that the colour is due to black mineral particles like titanium oxide, magnetite or hornblende, etc. The intensity of the black colour is also influenced by the moisture content; soils

in low lying situations and a high moisture content being darker in colour than similar soils on the higher slopes on which a sort of browning action is induced by the high temperatures and the drying effect.

The red or reddish-brown soils owe their colour to the oxides of iron and some highly ferruginous soils may be even dark in colour though not black like the black cotton soil. Even the ashy grey soils will become red or reddish in colour on heating, thus showing up their iron content.

THE STRUCTURE OF THE SOIL

A highly important physical characteristic of the soil is the structure. All tillage operations are designed with the object of giving to the soil the ideal structure required for the spread of the roots of plants, the holding, movement and retention of the correct amount of water, ample aeration and the spread and movement of plant foods. This is secured mainly by an arrangement of the particles of soil into such aggregates as will produce the largest amount of pore space and the largest amount of particle surface in any particular volume. Soils of different types differ in the facility with which they will assume or satisfy this condition, and the property is largely dependent upon the size of the particles of which the soil is naturally composed although important modifications can be made by manurial and other treatment.

The pore space in any soil is at a maximum in a clay soil and at a minimum in a sandy soil and intermediate in a loamy soil. The pore space of any particular soil can be calculated by first determining its apparent density and then using the formula $100 (D - d)/d$, where D is the true density (which may be assumed to be $2 \cdot 7$ for all practical purposes) and d is the apparent density, which can be easily found by the weight per unit volume. The greater the pore space the greater is the facility for the production of the ideal structure. The percentage of pore space of some types of soils are given below :

Finest clay soil	.. 52·94
Heavy clay soil	.. 48·00
Clay loam	.. 47·10
Loam	.. 44·15
Sandy soil	.. 34·40 (King)

In clay soils although the percentage of pore space is largest the advantage is largely offset or neutralised by its tendency to become plastic when wet and highly coherent and compact when dry. This tendency has to be corrected as it is in practice by additions of farmyard manure or green manure and of lime. Ploughing and cultivating at the correct time will bring about the crumb structure while tillage at the wrong time will have the opposite effect.

Chemical Composition and Properties of Soils

All soils being derived primarily from rocks, contain, in the ultimate analysis, the elements which have entered into the composition of these rocks. In view of the various changes that have taken place as the result of weathering, transporting and other soil-farming agencies discussed already, soils may have lost some of the compounds of the parent rock or the compounds may have changed into others or gained considerable additions especially in the shape of humus or organic matter from the vegetable kingdom or from marine or other aquatic life. The chemical composition will therefore reveal not only the various elements that may be present in it but also throw light on the manner in which they exist in the shape of particular compounds, their solubility or otherwise and the way they may react with compounds which may be added in the shape of manure.

Though many elements are contained in soils, only some of them are concerned in conferring upon them their agricultural or crop-producing value and therefore form the subject of study. The elements that soils may contain are hydrogen, oxygen, nitrogen, carbon, silicon, sulphur, phosphorus and chlorine among the non-metals and potassium, sodium, calcium, magnesium, iron, aluminium, manganese among metals; in addition, other elements can also be present in special cases in very minute quantities as 'trace' elements. Among those listed above, some are essential elements and others are not essential for plant growth. Even among those which are essential, some exist in such great abundance in soils compared with the quantity which crops may take up annually that a deficiency as far as crop requirements are concerned is never likely to arise. The elements which are essential for the growth of crops and of which a deficiency is likely to arise are those whose quantity in the soil has to be known and taken into consideration. Such a deficiency may occur in one of two ways, *viz.,* (1) by an absolute lack of it or its presence in too small a quantity, and (2) though present in sufficient quantities, by its being in a form which cannot be made use of by plants, *i.e.,* by existing in a non-available form. Chemical analysis will throw light on both aspects of the deficiency.

This class of elements comprises: nitrogen, phosphorus, potash and, to some extent, calcium. In view of the fact that they are both essential and likely to be deficient and requiring therefore to be added in the shape of manure to the soil, the term 'plant foods' is confined to them, although, strictly speaking, the name should apply to several other elements as well which enter into the composition of plant tissues as essential elements. In addition to these elements the quantities of certain other elements are also estimated in an ordinary chemical analysis of the soil; these are iron, aluminium, magnesia, sodium; the quantities of these also have some importance, as they are concerned in the reactions or changes that

may take place when particular manures are applied. In many cases, estimations are made of the 'acid radicles' also such as carbonic acid, sulphuric acid and hydrochloric acid in addition, which become particularly important in the study of alkaline soils. Special estimations are made when required, to determine the quantities of the available plant foods as distinguished from the total plant foods present in the soil.

Total and Available Plant Foods

It must be pointed out that as conducted at present, a chemical analysis does not give the full composition of the soil, including all the mineral silicates in it; by convention such a solvent is used with which the soil is treated in a particular manner that it will dissolve all the elements and as completely as may be ever deemed necessary for the needs of or possible by, plant life. The reagent used is hydrochloric acid of a particular strength which at the temperature and time prescribed for the treatment can dissolve out these quantities, which are then estimated in the solution by prescribed methods. In most soils the amount of mineral plant foods contained in the hydrochloric acid solution is found to be such as to suffice for the needs of a large number of successive crops of even an exhausting nature. It is rarely indeed that soils are met with which, according to this test, can be called poor or lacking in any of these plant foods. Indeed, if the total quantity of plant foods contained in an acre of soil 1′ deep (taken as equal to 3,000,000 lb. in weight) be calculated and compared with the quantities removed from an acre by any of the crops of the farm, the number of such crops that can be raised on that soil resource will be found to be astonishingly large. Nevertheless in actual practice the same soils are found to be in need of manures and to respond strikingly to the addition of one or more among the plant foods, showing that they were wanting or poor in those plant foods in spite of the apparent abundance. The explanation is that the plant food may be present abundantly as disclosed by this hydrochloric acid solution, but the same may not be in an available form. The need hence arises for some test by which the available plant food percentages can be estimated.

Available or Citrate-Soluble Plant Foods

For this purpose, the soils are treated not with a strong acid like hydrochloric acid but with a dilute solution of a weak acid, which may be comparable in action with the weakly acid sap or exudation of the rootlets, with the help of which plant foods are dissolved out and absorbed. The acid selected for this purpose is a 1% citric acid, with which the soil is extracted for a period of 24 hours. The method is known as the Dyer's method and is used for estimating both phosphoric acid and potash, the former to a greater extent than the latter. Other dilute acids are also used such as

very dilute acetic acid for the same purpose; there are also some rapid tests of different kinds, which are referred to in the chapter on "Manures". Considerable convention prevails in the interpretation of the result, generally based upon the extent of correlation of the quantity with crop response. Available phosphoric acid (P_2O_5) below 11 mg. % is taken as an indication that the soil is poor and needs phosphate manuring, and likewise in the case of potash a quantity less than ·01% is taken as an indication of potash deficiency. This conclusion may not apply to many Indian soils and crops; at any rate the data on the correlation of available plant foods with crop response are too meagre for fixing any such standard.

Results of Chemical Analysis of Soils

The information usually supplied as the result of a chemical analysis of soils may now be dealt with individually. They relate to the following: (1) Moisture, (2) Loss on ignition, (3) Nitrogen, (4) Iron oxide (Fe_2O_3), (5) Alumina (Al_2O_3) (or together as oxides of iron and aluminium), (6) Lime (CaO), (7) Potash (K_2O), and (8) Phosphoric acid (P_2O_5).

1. *Moisture.*—This is the amount in the soil in its air-dry condition. All soils are prepared for analysis by thorough drying in the air and are taken up for analysis only in that condition. This amount may vary from about 2–7% according as the soil is sandy or clayey. If the soil was an alkaline soil and contained much salts it may contain a higher percentage, as the salts usually absorb moisture from the air. The moisture content is estimated by drying the air-dry soil at 100° C. Of course this moisture, whether it is high or low, is of no use to plants as it cannot be withdrawn by the roots.

2. *Loss on Ignition.*—The loss in weight sustained by the dried soil when it is heated strongly over a Bunsen flame (or ignited) gives the 'loss on ignition'. This loss is due to the fact that the organic matter in the soil is burnt away and the amount of such loss is a measure of the organic matter content of the soil. This is not strictly so, because the loss may arise by the decomposition of carbonates with the escape of carbon dioxide and on the loss of water in chemical combination; on the other hand, some of the lower oxides of iron may become oxidised into the higher oxides which means an increase in weight. Whether these two actually take place or not in the particular soil concerned, the net loss is taken as a measure of the organic matter; for more accurate determination a different method is used. As a matter of fact, it is reported that in many cases only about one-third of the "Loss on Ignition" figure represented the organic matter content.

3. *Nitrogen.*—This important constituent is estimated by a separate determination and the figure gives the total nitrogen in the soil. When nitrogen in the form of ammonia and of nitrates is also required, separate estimations are made; usually however in the

ordinary soil analyses the total nitrogen is given. If the former two are given, then the nitrogen status of the soil for immediate use becomes known, but these latter form only a small proportion of the organic nitrogen.

4. *Insoluble Residue.*—This is the portion left after the treatment with hydrocholoric acid and after all the material dissolved by the acid has been completely removed. It is mainly made up of silica, but contains in addition the fine particles of such minerals as cannot be decomposed by acid. As far as the cropping value of the soil is concerned it is inert material. The sandy and coarse soils contain more of this constituent than the clayey soils.

5. *Oxides of Iron and Aluminium.*—These are often given together, but sometimes separately estimated and given also. They do not furnish much useful information regarding the fertility of the soil. When they are high especially in relation to the silica content, the soils are likely to be clayey. A high percentage will also indicate that phosphate manuring with soluble or semi-soluble forms, like superphosphates, ammophos, etc., are likely to be largely neutralised or rendered insoluble, by these oxides. Phosphate manuring in such soils will have to be carefully studied and the kind of phosphate to be applied, its method of application especially in regard to placement and the quantities to apply will have to be looked into in detail and decided.

The ratio of the oxides of iron and aluminium taken together, to the silica content (*i.e.,* molecular weights of the percentages) is a figure much used in the study of the clay fraction in soils. The ratio is put down as Silica$|R_2O_3$ where both the oxides are taken together or as Al_2O_3 where this alone is taken, which is regarded as the correct procedure. It is found that as this ratio increases, the colloidal properties peculiar to clay become more prominent or developed, such as stickiness, shrinkage on drying, and power to absorb water, ammonia, etc. A low ratio (about 2 and below) indicates soils nearest to the parent rock in their formation, while high ratios (5 and above) in the case of soils developed after most of the weathering and many forms of transport have taken place, such as old alluvial soils. As a rule the higher the ratio the more fertile is the soil taken to be.

6. *Lime.*—This figure gives the percentage of total calcium oxide in the soil, as the whole of the lime in the soil is dissolved out by the hydrochloric acid. This figure, though it gives a useful indication of the lime content and may be generally sufficient, does not actually indicate if the soil is in need of lime and if so, how much should be added. For answering this question a determination is made of the pH of the soil, *i.e.,* of its water suspension. This figure or pH of the soil shows the reaction of the soil, *i.e.,* whether it is acid, or neutral or alkaline, giving such reaction a numerical expression. The pH value of a neutral soil suspension

is about 6·0 or 6·5, values below this figure indicate an acid reaction and values above it indicate an alkaline reaction; the pH value may go down to 4, if the soil is extremely acid, and to 9 or 10 in 'alkaline' soils. The following (taken from *Soils* by G. W. Robinson) may be adopted for guidance.

Between	4·0 and 5·0	..	acid
,,	5·0 and 6·0	..	moderately acid
,,	6·0 and 7·0	..	slightly acid
,,	7·0 and 7·5	..	,, alkaline
,,	7·5 and 8·0	..	moderately alkaline
,,	8 and 9	..	alkaline
over	9	..	extremely alkaline

The pH value of the soil is readily determined and from this figure the 'lime status' of the soil and the need or otherwise for the application of lime is decided. Only those soils whose pH is below 6 or 6·5 are considered to be in need of lime, the lower the pH the greater being the need for liming.

Rapid colorimetric tests are also applied for determining the reaction (B.D.H. method) of the soil, which is capable of being used on the field itself, and is suitable for outdoor work; these values are also used in deciding the need or otherwise for lime, and they generally agree with the reaction, as shown by the pH values. In a series of pH determinations made on 43 different types of Indian soils, the values for the different types were found as under: per humid 5·21, humid 6·84, semiarid 7·72, arid 7·35 according to climatic types; and red 5·56, pink and grey 7·20, brown 6·72, black 7·67, calcareous 7·54 according to colour types (S. Das and others, *Ind. Jour. Agri. Sci.,* June 1946).

The methods are more or less analogous to differentiating the total from the available plant foods in respect of the others already referred to. The available lime in the soil may also be determined in a like manner and the lime requirement judged. If the available lime goes below 0·2% it is taken to indicate that the soil is deficient in lime and is in need of liming; if the total lime itself should go below this figure then the need will obviously be more.

The lime content of Indian soils of the red, light red loams and all grey alluviums has a range from about ·3% up to ·7%. The black cotton soils generally have a high lime content which may go up to 5%. Many of the highly ferruginous soils of the coffee estates of South India are acid or mildly acid in reaction, and liming is generally recommended. An exception however is when the crop grown is tea, which requires a mildly acid soil.

According to Vegelar, the following crops prefer an alkaline reaction or soils with a pH of 7 and upwards: grain crops, oilseeds, jute, cotton, agaves, to which may be added all the legumes. A neutral or nearly neutral reaction is preferred by maize, millet, tobacco, sugarcane, coconuts, coffee, cocoa. Markedly acid reaction is preferred by oil palms and tea.

It must be cautioned however that these determinations of the soil reaction are not always a reliable test for the need of lime nor for the quantity required. It is only where actual correlations have been established by crop tests on such soils and by practical experience, that they form a reliable guide, but they certainly indicate a basis on which a crop test should be planned.

7. *Potash* (K_2O).—The chemical analysis gives the total percentage of this important plant food in the soil (in the hydrochloric acid solution). The percentage may range from 0·2 to 1% in ordinary soils, but is likely to go up very much higher in alkaline soils. In Indian soils the range is from ·05 in poor soils to 0·6% in good red loams, rising to even 2 or 2·5% in black cotton soils.

8. *Phosphoric Acid* (P_2O_5).—Next to nitrogen this is the most important plant food, which is determined in the analysis. As in the case of the other constituents, the percentage given is the total phosphoric acid. Most soils contain only very small quantities and the range is generally from ·05 to ·2 or ·3%. British soils contain from ·1 to ·2%. In Indian soils the quantities are still less, although in certain types as in the case of the soils of the Panjab and U.P. the maximum may go up to ·25%. Egyptian soils are said to be rich and to contain ·28%. Pasture lands in New Zealand and Australia are said to be very rich, with a range of ·75 to 1%. Nearly the whole of it is in the non-available or insoluble form and the available or citrate-soluble percentage is usually determined also and given. At least 25% of the total phosphoric acid should be citrate-soluble in good soils. Phosphoric acid goes quickly into insoluble or difficultly soluble forms in the soils, and the presence of a larger percentage of iron and alumina helps in the process.

The phosphoric content of some Indian soils is given in the next chapter.

Limitations of Soil Analysis

The chemical analysis of soils and the chemical study of the reactions therein furnish no doubt information of great value in respect of many aspects of the soils, but nevertheless it must be said that the result of a chemical analysis is not such as to help to the extent desirable in assessing their crop-producing power, or as compared with other soils or in giving correct guidance in deciding as to the manures to be used and their quantities, or if any manures are needed at all. The remark made by Prof. King some 50 years ago (1895), *viz.,* "it is very unfortunate for agriculture that it should seem necessary to admit that the results of soil analysis as they have been made can and do throw but a very dim and uncertain light upon either the condition or the amount of plant food a soil may contain" still seems to be substantially true, as it is echoed even in 1945 by the remark "No means

exist of translating the results in terms of crops the soil will carry" (*The Soil*, by A. D. Hall, revised by G. W. Robinson, 1945). Many other methods therefore, chiefly that of field experiments and others (referred to in the chapter on "Manures"), have to be resorted to in additon: but it cannot be denied that chemical analysis affords considerable guidance and a useful basis for the carrying out of such field or other experiments, and certainly is able to indicate what soils have to be avoided, and in what way these soils can be improved.

INTERPRETATION OF CHEMICAL ANALYSIS OF SOILS

Subject to the many limitations mentioned and also to any judgment arrived at by a personal inspection of the area concerned, the figures which are obtained by a soil analysis may be interpreted in terms of the quality of the soil in accordance with the following key (suggested by Dr. Sahasrabudhe):

	Rich	Good	Fair	Poor
As regards nitrogen ..	More than ·1%	·06– ·1%	·03–·06%	Less than ·03%
P_2O_5—				
For non-clayey soils ..	·1	·06– ·1	·03–·06	·03
For clayey soils ..	·2	·1 – ·2	·05–·1	·05
As regards potash—				
For non-clayey soils ..	·25	·15– ·25	·05–·15	·05
For clayey soils ..	·3	·2 – ·3	·07–·2	·07
As regards lime ..	2·0	·5 –1·5 or 2	·1 –·5	·1

CHAPTER III

THE SOILS OF INDIA

Regional Types.—The soils of India covering as they do an immense land mass large enough to be called a sub-continent, comprise a large and interesting variety, brought about by the diverse and striking physical features of the country, such as its location within the zone extending from lat. 7 N to lat. 35 N, by its diversity, in rainfall and climate, its huge mountain and river systems and by the work of civilised mankind through a period of fifty centuries or more. The gigantic Himalaya mountains which shut in the continent like a cyclopean rampart from end to end on its north, and north-west, has by slow denudation given rise to the immense stretch of the so-called Indo-Gangetic alluvium, through the transporting agency of three mighty rivers and their confluent river systems. This soil type which is remarkable for its uniformity (barring comparatively small exceptions) over a very large stretch of country, covers a region estimated at some 300,000 square miles.

South of this vast tract and of the Vindhya Mountains, lie the regions of the Deccan and Peninsular India, which consists of three distinct zones, *viz.,* the high mountain ranges of the Western and to some extent the Eastern Ghats, the high and extensive plateaus, and lastly the plain country much of which is drained by several rivers. The first is subject to incessant wash by the torrential rains and a steady denudation of the soil takes place. Over the comparatively flat plateaus, are to be found many different types of soils, the famous Deccan trap rock soils, stretches of black cotton soils, lateritic and other red soils. Lower down in the plains are the alluvial soils of the many river systems, finishing up with the rich deltas, near the river mouths or estuaries.

Quite a distinct and rather unique feature is presented by the arid sandy desert of Rajputana and of Sindh, contiguous with the great gap north of the wall formed by the Western Ghats, over which hot winds blow without any impediment, shifting the fine sand miles inland.

Extensive irrigated cultivation has brought into existence vast large stretches of alkaline soils creating a problem by itself. Although this is only a transformation brought about by human agency, and not a natural formation like the other soil types, still as it is likely to arise under similar circumstances in many parts of India, it is sufficiently important both as it exists and as a potential soil type. Isolated regions where the soil is naturally alkaline and unfit for cultivation without reclamation also form a feature though comparatively insignificant.

The Parent Rocks and Minerals.—A variety of parent rocks and rock-forming minerals has been provided by the great geologic

agencies of upheavals, subsidence, stratifications, contortions, both igneous and aqueous in character, which have brought about the present configuration of the land surface, and these have been the source of the soils of different kinds in the country. Ancient granite forms the parent of most Indian soils; gneisses, schists, chlorite and hornblende schists, banded ferruginous quartzites, clay slate, limestone beds, sandstones, limestones of marine origin, and lastly the peculiar laterite rocks which traverse the country from the southernmost end in two arms along the two coasts and also appears in large isolated patches in the interior, constitute other parent materials. A very important set of parent rocks are the Deccan trap rocks, which are the product of successive lava flows that have cooled in layers, giving rise to the peculiar step-like formation. Soils of great fertility have resulted from the easily decomposing minerals forming these rocks and they form the characteristic feature of a great part of the Central Deccan Plateau. The rock formations of the Himalayas themselves which have given rise to the Indo-Gangetic alluvium now several thousand feet in depth are of course the parent of the largest soil formation, although the alluvium itself may now be regarded as the parent of the soils in the lower reaches of the rivers.

The minerals from which the various soils have been formed and which influence the chemical composition of the soils are generally the same as or similar to those in other parts of the world. They are the following:

(1) Quartz, which is silica in its crystalline form; (2) complex silicates of aluminium, iron, magnesia, lime, potash and soda which comprise (*a*) the various felspars such as orthoclase which is the silicate of aluminium and potash or soda (albite) or of lime (calcium felspars), (*b*) hornblende or silicate of aluminium, iron, magnesium, and lime, (*c*) mica, a very intractable silicate of aluminium and soda or potash, (*d*) ferro-magnesium silicates called olivine, talc, etc., (3) limestones and dolomites and magnesites which are carbonates of lime and magnesia; (4) zeolites or soluble silicates of soda or potash; (5) iron pyrites; (6) ores of iron, being oxides and hydroxides of iron, including the "pea iron ore" of laterite soils; (7) bauxite or hydroxide of aluminium; (8) apatites or phosphates of lime. Under special conditions and situations, soils containing many other minerals may also be present either in a pure form or in a weathered condition; sands containing bits of graphite, oxides of titanium, crystals of monazite are examples.

The usual components of the soil are present either pure or in their weathered condition. Among the former are quartz, and among silicates mica. Others exist in their weathered forms, or what amounts to the same as far as utilisation by crops is concerned, in very fine particles comprising the clay and silt fractions of the soil.

Much of the physical condition described as stony, coarse or gravel, arises from the structure of the rock, the size of the crystals composing it, the methods of cleavage, the compactness of layers, etc. Pegmatities, porphyrites, quartz veins, banded quartzites and much broken schists give rise to coarse and open soils, while the highly weathered felspars to clayey soils.

SOIL TYPES OF INDIA

The soils of India are classified in government records according to their agricultural value or crop-producing capacity. This is generally intended for the settlement of land assessment by the Department of Survey and Settlement. The most elaborate classification of this kind is that which is adopted in Bombay and copied in Mysore. The basis is composed of many factors, like colour, depth, proportion of clay, sand, mixture with stones and gravel, and so on, and the division comprises nine classes each of which is subdivided into three orders. Defects of various kinds are also noted and allowed for. The system is almost perfect, for the purpose intended. In other provinces, the basis is likewise agronomic but the classification is very simple. Soils have also been classed according to their geological origin. Soils are also classified according to their fitness for particular crops, which is an index of their quality, helpful to the Settlement Officer in fixing its assessment. All this is on a provincial basis and therefore is different in the different provinces.

The Predominant Types.—On an all-India basis, three broad types are recognised as the predominant types of soils in India. They are :—(1) the Indo-Gangetic alluvium with which may be included the deltaic alluviums of Peninsular India, (2) the red so-called laterite soils with their variations, and (3) the black cotton soils.

1. THE INDO-GANGETIC ALLUVIUM

The characteristics of each of these may now be described :

This type occupies the flat plains of North India from the Indus Valley in the west to the Brahmaputra Valley in the east, in one unbroken stretch. It is of enormous depth which is said to be over 3,000′. It is throughout a light loam, often with much sand so as to be called, a sandy loam. It is loose and lacking in cementing clay or colloids and is liable to be shifted and blown by the wind. Its uniformity is most remarkable, there being no mixture of stones or pebbles anywhere, so much so, that it is remarked one cannot pick up a stone to throw at a dog in that vast stretch of country. The region is singularly free from hills or other undulations except for the deeply eroded surfaces here and there. The flat surface makes drainage, where necessary, difficult. A large portion of it lies in the arid rainless districts of the Panjab

and Sindh, on which considerable salts have accumulated and which have become prominent under the extensive irrigation systems of that region, leading to the formation of alkaline soils. Their sandy character makes them very porous and it is only on these soils of India that water, whether from rainfall or irrigation, may be said to percolate to some considerable depth and the loss of plant food and water by this cause is of some significance. Their physical condition makes them very easy of tillage, ploughing with mould-board or large wooden ploughs being comparatively easy. They are almost entirely of one uniform colour, being grey or buff or 'khaki'. Where conditions favour erosion, gully erosion is very serious and often a perfect network or maze of such gullies, very narrow and steep or as shallow creeks or rivulet-like gullies may be seen. Irrigation systems are extensive, and a multitude of canals traverse it. Underground water is also plentiful in these deep light soils and irrigation by pumping from tube wells is an important feature. Although these may be said to be the broad characters, variations do occur which is inevitable in a stretch of this magnitude, due in places to the outcrops of isolated hills which traverse parts of it. The Aravalli hills, various limestone beds usually as concretions, sheets and hillocks of laterite, have each some share in these variations.

The soils are rich agriculturally and there is hardly any crop of importance which is not cultivated on them. Crops are also usually more luxuriant on them, due probably to the facility for free and extensive root development. Crops considered typical of black cotton soils also grow luxuriantly, like wheat, linseed and Bengalgram. The soils also admit of growing a crop like sugarcane (which elsewhere is never grown without irrigation) solely with the rainfall without any irrigation. Wheat, rice, bajra and maize are important grain crops, mustard, rape and many brassicas, linseed, castor, gingelly and every kind of pulse crop including peas and berseem, sugarcane, tobacco, sannhemp and jute are among the large variety of crops cultivated to perfection on these soils.

The soils are "deficient in phosphoric acid, nitrogen and humus but not generally in potash and lime" according to Raychaudhari, but soils containing a markedly high percentage of phosphoric acid can also be found among them. For instance, Parr and Bose give the following figures as the phosphoric acid content of certain soils which shows the range :—Multan ·533, Lyallpur ·351, Montgomery ·207, Rawalpindi ·198, Ambala ·139, Hissar ·138, Karnal ·130, Lahore ·102, Partabgarh ·18, Pusa ·10, Patna ·13, Cawnpore ·08, Kanki ·077.

2. The Red Loams

The red loams form an extensive type in India, and may be said to be as distinctive of Peninsular India as the light-coloured

sandy loams of the Indo-Gangetic alluvium are of Northern India. The red soils, however, have to be divided into two somewhat different kinds, one of which is unmistakably derived from the lateritic rocks and the other which cannot be said to be so derived. There is, however, a considerable mingling of one with the other, so that a lateritic taint, if it may be so called, cannot be altogether excluded from the latter.

The typical lateritic soils are to be found all along the Eastern Ghats, both foothills and coastal belts, in the great plantation districts of South India, along the west coast almost up to Bombay, and on the east coast both in patches and along the coast, and in many parts of Orissa, Chota Nagpur, and parts of Bengal and Bihar. They are generally clayey loams, and clayey soils, with the lateritic rocks showing as outcrops in many places; they contain somewhat as a distinctive sign small ironstone or limonite pebbles (called 'pea iron ore' sometimes) scattered in them throughout their depth; they are very hard when dry, are not easily permeable, but can be ploughed just as easily as loams after they are well moistened by a heavy rain. Though under cultivation good crops are grown, in many places they tend to be either bare of even grass vegetation or to sustain only scrub and thorny bushes. The red colour of the soils and the cloud of red dust which during the hot weather settles everywhere in the towns and villages in these tracts are both very characteristic.

Their composition can be seen from the table at the end of this chapter. They have a high content of iron, but lime, magnesia and potash are low, while many of them contain a good percentage of phosphoric acid. The pellets of pea iron ore of which there is always a large admixture are said to contain up to 3% P_2O_5.

While these are the primary formations of red soils in the close proximity of laterite beds and rocks, the soils become largely mixed up with various other kinds, both physically and chemically, the outward characteristic being one of gradual lightening of the red colour, some openness of texture, a normal and even luxuriant plant cover and a higher agricultural value generally. In the forest clad ghats occupied by the coffee, and tea estates, the soils are largely altered by the organic matter from fallen leaves; and on the plains and plateaus with the addition of soil brought down by the rivers and streams. These soils partake therefore to varying degrees of the character of the red soils proper derived from laterite. They are generally hard when they are dry but after a good shower of rain are fairly easy to plough, though not so easy as the lighter red soils. They form the bulk of the dry lands in Peninsular India and a large variety of crops like ragi, jowar, many millets, various pulses, American cotton, castor, gingelly, groundnuts, many permanent crops like cocoanuts, mango, etc., are grown, the success depending upon the extent of the rainfall. Crops can be grown

only during the rains, as they are not sufficiently retentive and cannot carry a crop through after the rains cease. They are well suited for irrigated garden cultivation being well drained garden loams and a large variety of these crops including sugarcane is grown very extensively in this way. Ridges and high lying areas are almost occupied by the red soils, where they are subject to much surface wash. They are all often deep and in places surprisingly uniform to great depths of even six or more feet. Washed down into the lower levels into tank beds and rice soils, they become greatly altered by admixture with dark clay, manure, lime and vegetable debris and the surface becomes somewhat black or dark in colour, although lower down the red colour may be seen.

They may be of two classes: (1) the red soils of the hills and plantations, and (2) the red soils of the plains. The former are rich in nitrogen, moderate to low in phosphoric acid and high to moderate in potash. The latter are poor in both nitrogen and phosphoric acid, moderate in potash. Both contain a high percentage of iron and alumina, the former being more ferruginous. The lime content of both types is low to moderate.

3. The Regur or Black Cotton Soils

These are typical soils occurring in many parts of India, but confined almost entirely to the south of the Vindhya Mountains and the Malwa Plateau. They are characterised by their deep black colour (though sometimes this tint may be less deep and greyish black). When wet the soil behaves like clay, being sticky; walking or driving over wet black cotton soil is a trial and large lumps of the wet soil stick to the feet and the cart wheels. As the soil dries, it crumbles into loose crumbs quite unlike a clay soil. In the hot weather the soil is loose almost like the surface of a hoed field. It has a high water-holding capacity like clay and is very retentive of moisture. It is cabable of absorbing much moisture from the atmosphere, what is lost by evaporation in the day being generally made up by absorption at night. Crops can continue to grow even after the rains cease if once they have become well established, which is due to its great retentiveness of moisture. Ploughing is very difficult and large heavy ploughs have to be used, requiring strong bullocks. In the hot weather the soil cracks to great depths and becomes very hot, a temperature of even 60° to 70° C. being reported. They occupy large stretches in South Madras, the Ceded Districts, in Hyderabad (Deccan) in Southern, Central and Northern Bombay, and in the Malwa Plateau.

They are considered the most fertile soils but are mostly suited for dry cultivation. They respond to irrigation liberally also but irrigation has to be practised with considerable care. A suitable crop rotation with semi-dry crops is necessary, and irrigation itself

is to be given preferably in fields laid out in furrows and ridges. Where sugarcane is grown, the fields are thus laid out in deep trenches and ridges, on what is called 'the Java system', which is however the general local practice also on heavy soils. On many black cotton soils, irrigation is likely to bring up salts to the top soil and to render them alkaline, if irrigation is regularly practiced ; the provision of effective drainage becomes very necessary in such soils, if irrigated crops are grown.

The crops of the black cotton soils are rather distinctive. As the name implies, cotton is an important crop, and even in cotton it is the indigenous or Asiatic varieties which are well suited rather than the American varieties. The later can be grown also, but are subject to the risk of disease in some seasons. Among the grain crops, jowar (both the early and late season varieties), Italian millet, bajra and wheat are the common ones and ragi is grown only to a very small extent. Among pulses, Bengalgram is distinctive for the black cotton soil, where it grows principally with the underground soil moisture alone, like the other post-rainy season crops. Among miscellaneous crops are, coriander and menthya. Dry land mulberry is a favourite crop on the black cotton soils of Southern Mysore, where it does remarkably well. The retentive nature of the soil, especially when it has much depth in addition, makes the dry cultivation of several crops possible which are ordinarily grown only under irrigation in other soils. Such crops are chillies, garlic, onions and tobacco ; the latter gives a fair stubble crop also or ratoon crop, on these retentive soils after the harvest of the first crop.

Black cotton soils, presenting as they do a loose surface condition, are subject to serious erosion. Erosion is generally of large stretches of the surface called "sheet" erosion leading eventually to shallow narrow gullies also. The dead level plains with a very little slope occupied by these soils favours this kind of erosion, and this is a serious difficulty agriculturally. Embankments both on a large scale for protecting the fields of whole villages, and on a small scale for protecting individual fields have been resorted to, the bunds being often riveted with stones at great cost.

A characteristic of black cotton soil husbandry is that the fields are very large and likewise individual holdings also, as holdings go in this country. Farming is of the "extensive" type and a large variety of bullock drawn implements is in common use and many labour-saving devices are resorted to. Many of these tracts are also tracts of low rainfall.

In chemical composition black cotton soils are found to be rich soils, nitrogen and lime being high, and the latter often very high, while potash and phosphoric acid are well provided. A high lime content is often accompanied by a high content of soluble salts, which may make the soil even unsuitable for cultivation.

Some of them may be even 'marly' from which limestone or 'kankar' may be quarried for lime burning.

How the Black Cotton Soils were Formed.—The origin of the black cotton soil is not well established, nor the factor which accounts for the black colour. In the plateau of the Bombay Deccan and Central India, the soils owe their origin to the Deccan trap rocks which adjoin or traverse the region. In other large black cotton tracts such as those in the Ceded Districts of Madras, of the districts of Madura, Ramnad and Tinnevelly and Mysore and Coimbatore, this cannot be the case because the trap rocks do not traverse these regions. It is considered (1) that these soils may have been derived from the ordinary red soils themselves, as the result of very moist conditions, or actual submergence, or (2) that they may have been formed under these conditions directly without the formation of the intermediate red soils. These black soils are probably derived from calcareous felspars while the red soils are derived from potash felspars. It is a noteworthy feature of the black cotton soil tracts that they are remarkably flat in surface looking almost like immense dried up lake bottoms. The black colour is put down variously as due to organic matter itself, to organic matter much modified owing to a large lime content in the soil, to the presence of titaniferous magnetite or other oxide of iron, to some peculiar combination of iron with the origin matter or with the complex silicates and lastly to some extent to the moisture content itself. Another noteworthy feature is the high lime content usually present in all these soils. The lime is found in nodular concretions or as finger-like formations either mixed with the soil or as underlying in irregular layers or in patches. It is thought that these concretionary formations are derived from the lime originally present in the surface itself, by being dissolved by water containing carbon dioxide in solution and retained at short depths on account of the lack of sufficient rainfall to leach it down to a greater depth or out of the soil altogether.

4. Other Black Soils

Some black soils of extraordinary fertility are derived from the beds of tanks, either when they dry up or when they are breached and the beds made available for cultivation. The reason for such fertility is obvious, as the soils contain the fine and fertile soil washed down from the uplands, the remains of fish, molluscs and the like, with the rich lime content and phosphates of the shells, the organic matter from the water weeds and moss growth and the high nitrogen content resulting from these animal and vegetable remains. Though clayey and cracking in thin flakes, as is peculiar to the thin top layer of clay or developing deep cracks, the soil when carted to the fields dries into a crumbling mass in the heaps, in the same way as the black cotton soil does. When the tank beds are cultivated, crops

grow with extraordinary luxuriance and often too rank, on account of the great fertility. When carted to the fields whether dry land fields or irrigated rice land, these soils improve the latter both in the physical condition and in their plant food content. They form the bulk of the soils under tank irrigation, but may be rather shallow and underlaid by the ordinary red loam. Rice, plantains, sugarcane, turmeric, many kinds of yams, areca and many kinds of fruit and vegetable crops including cabbage and the like, are grown on these soils. They are retentive of moisture and will allow of considerable intervals between irrigations. They will however require a heavier rainfall than the loams and lighter soils in order to fit them for ploughing, but this is not a real disadvantage as irrigation is generally available and the soils can be given an irrigation and softened for ploughing.

5. Alkaline Soils

Another important soil type in India is the alkaline soil. These can hardly be called agricultural or arable soils, because they are either totally unfit for cultivation or permit of only poor and precarious crops. They occupy however very extensive tracts, on which crop raising is impossible, and which therefore have to lie unused by the population although the need may be great. The U.P., Punjab, Sindh and the Bombay Deccan are the provinces seriously affected. The reclamation of alkaline soils in the U.P. was at one time such a serious and important problem that as early as the years 1878 and 1879, it formed the subject of inquiry by a Special Commission in that province, which drew up a very valuable report containing much useful information. Off and on, both here and in other provinces, special investigations are being carried out for the purpose of devising suitable methods of improving or reclaiming these soils. It is also a growing menace, following in the wake of almost every large irrigation scheme. The matter may therefore be dealt with in a little more detail than we have done in the case of the other classes of soils.

The trouble with alkali is not confined to any one particular type of soil. It is extensive in the Indo-Gangetic alluvium, from the Indus Valley, through the Punjab canal tracts, into the U.P. It is serious in the black cotton soils of different kinds in the Bombay Deccan, in Madras and Mysore, mostly in the canal-irrigated tracts. It can be seen in the red loams and laterite soils in many parts of Madras and Mysore.

Signs of Alkalinity.—Outwardly alkaline soils are characterised by one or more of the following features: (1) a white or whitish incrustation or efflorescence on the surface in patches, or (2) a black incrustation or skin on the surface; (3) the presence of water in puddles here and there especially in the depressions, even long after the rains may have ceased; (4) a hard rather tightly stretched surface crust; (5) if eroded surfaces are exposed, much crumbling and

weathered rock and sometimes limestone concretions or deposits may be seen on the exposed face, fairly near to the surface and at varying low depths; (6) normal vegetation is very sparse or even *nil,* and when present, comprises scrub and thorny low-growing shrubs or so-called "salt bush" and other salt-tolerant grass or other plants. Certain trees are also peculiar, notably the wild date and babul. If crops are grown it is generally rice under irrigation, and the stand of the crop, notably the lack of tillering and general weak growth of leaves, reflect the trouble with the alkali.

The immediate cause of the infertility or barrenness of these soils is the fact that the soil within the root range is so highly charged with soluble salts that the soil solution proves injurious to vegetation, either to the extent of total barrenness or to varying degrees of unsuitability. These salts may comprise (1) those which are directly injurious, or (2) though innocuous ordinarily or even directly beneficial as a plant food, become injurious on account of the high concentration or (3) by a combination of both.

The salts belonging to the first category are the carbonates of soda and chlorides of soda, the former much more particularly than the latter. The carbonates can dissolve any humus or plant remains that may be present in the soil and such solution being black in colour and drying on the surface of the soil, gives it the black colour associated with what is called "black" alkali. This form of alkalinity is the worst type.

Other salts like sulphate of soda, chloride of sodium, bicarbonate of lime, sulphate of lime and salts of potash belong to the second category. Although they are harmless in dilute soil solutions, they bring about 'alkalinity' and its harmful effect by the larger quantity in which they are present in the soil, leading to a high concentration in the soil solution. Even salts like nitrate of potash or lime, which ordinarily are salts of direct and high manurial value are sometimes present in such soils and cause harm by their high concentration in the soil water.

The injury to the soil by the presence of these salts is due to both physical and chemical causes. The salts, especially of sodium, bring about a deflocculation of the fine particles, intensifying the clayey character, making the soil almost impervious to water, very sticky when wet and hard when dry. If the soil is already clayey it becomes worse, and if it is light and loamy then it is made highly clayey in its stickiness and other conditions.

Salt Content of Alkaline Soils.—The following analysis of some alkaline soils of the Bombay Deccan will show the extent of the concentration of the soil water, the quantity of sodium present, the clay content and other peculiarities of alkaline soils referred to above:

	Depth	Total sol. salts %	Sod. carb. %	pH	Calcium carbonate %	Clay %
Sample I ..	0–12″	0·69	·011	8·9	5·26	50·0
	12–24″	1·14	,,	8·8	6·13	56·00
Sample II ..	0–12″	·31	,,	8·7	8·02	59·50
	12–24″	·93	,,	8·66	8·85	60·75
Sample III ..	0–12″	2·28	,,	8·43	10·95	5[illegible]·75
	8–19″	·83	,,	8·74	11·82	43·00

(J. K. Basu and V. T. Tagare in *Ind. Jour. Res.*, April, 1943.)

It must be pointed out that concentrations exceeding 0·1% in the soil solutions round the roots is considered unfavourable and ordinary wilting may begin thereafter, if this is prolonged. Exceptions are also noted, as in the case of some soils in Sindh where a concentration of even 0·5% is said to be tolerated. It will be seen that the salt content in the above alkaline soils exceeds even this limit in the top soil. In the alkaline soils of the Nira left bank canal (Bombay Deccan) the total salts present in successive 6″ layers from the top were as below :—3·05, 0·97, 0·94, 0·83, 0·45, 0·47, 0·43, 0·46 (*Soils of the Bombay Presidency,* by Dr. Sahasrabudhe).

The particular salts responsible for alkalinity and their percentage in samples of Indian alkaline soils can be seen from the following analysis of alkaline soils :—

Depth	Percentage of			
	Sodium carbonate	Sodium sulphate	Sodium chloride	Total sodium salts
0–2½ feet ..	·214	·274	·105	·593
3–4 ,, ..	·272	·227	·181	·680
0–2½ ,, ..	·026	·050	·005	·085
3–4 ,, ..	0	·056	·175	·231
0–2½ ,, ..	·582	·254	·210	1·046
3–4 ,, ..	·321	·054	·081	·456
0–2 ,, ..	·789	·054	·046	·899

How the Alkaline Soils are Formed.—Alkaline soils are largely found in regions of very low rainfall in the so-called arid or semi-arid regions of the world. It is noteworthy that the regions are remarkably level, or like a flat-bottomed basin; such rain as falls has little chance of flowing off as surface wash, but has to sink into the soil; nor is there, for the same reason, much chance for the

water to move out laterally into lower levels. The salts become conspicuous and of importance in agriculture when these soils are brought under cultivation or attempted to be cultivated. Under irrigation, the trouble greatly increases and becomes a serious problem. The salts which are thus naturally present in alkali soils and which make themselves conspicuous and a serious problem under irrigation arise from the following causes :

1. Primarily the salts are the result of the weathering of the rocks which traverse the region ; the weathering is fairly rapid under these arid conditions and much soluble material is formed. These are dissolved by the rains which carry them down into the lower layers, deep or shallow according to the quantity of the rainfall. As this is however very poor in these tracts, the salts are not washed down very deep but are left not far from the surface. The tract is also flat, so that little water can flow away and carry with it part of the salts in solution. The water merely soaks into the soil and into the subsoil. With the cessation of the rains, the soil moisture begins to creep up through the soil by capillary rise. This is greatly favoured by the position of the moisture close to the surface, near enough for the capillary force to act effectively. The evaporation from the surface soil also helps the rise, while the dead level surface precludes any diversion laterally. The rise therefore goes on unimpeded and once the water evaporates, the salts are left on or near the top soil. Such a process going on year after year results in a zone of soil near the surface which is highly charged with salts. The rains being scanty, the movement downward and washing out or leaching of the soil cannot take place, the process being too slow to keep pace with the factors tending to bring it to the surface.

2. Accessory factors may also come into play, by the formation of stiff impenetrable pan of salt-laden clay, below the surface, which becomes another cause of preventing the downward movement of the salt-water with the salt in it.

3. Sometimes the alkali soil plain may be like the bottom of flat plate or shallow basin and a certain amount of salt-laden water may flow on to it from the surrounding slopes and add further to its salt content.

4. When an irrigation source is created for irrigating these regions, conditions become very much accentuated for an increase in the salt content of the soil within root range of crops. Irrigation is either from tanks or canals drawn from rivers, but in both cases the water has to be carried at a higher level than the surface of the fields, for ensuring a proper flow by gravitation on the fields. The result is a rise of the water-table under the fields, more salt is dissolved in the lower layers and water rises more readily to the surface with the dissolved salts in it, which are deposited at and near the surface when the water disappears by evaporation. It is in the wake of large irrigation projects which have been executed for the special benefit

of these extensive tracts of poor rainfall that the alkali trouble has been intensified. For these reasons, irrigation has brought up alkali even on land not suspected to be alkaline and on which dry cultivation was being successfully carried on. The root-cause is of course in the soil itself, due to the accumulation or large production of soluble materials from easily weathering rocks. If the soils are in a semi-arid or arid region, definite alkaline soils are formed, even without irrigation, which latter only accentuates the condition and makes it more serious.

5. To a small extent salts may be brought into the fields in the irrigation water itself, if it should traverse alkaline tracts and carry much dissolved salts. This is rather of rare occurrence, at any rate as far as the production of alkaline soils is concerned.

The Improvement and Reclamation of Alkaline Soils

Methods of reclaiming alkaline soils are based upon the following objectives, *viz.,* (1) the removal of the alkaline salts from the soil; (2) prevention of the entry, in whole or part, of the salts into the soil or the root range of the crop; (3) the neutralisation of the alkaline salts and converting them into harmless or less harmful salts; (4) improvement of the physical condition of the soil, for making the removal of the salts by drainage easier; and (5) the removal of the soil itself and its replacement by alkali-free soil or by diluting it and lowering the concentration. How these objects are achieved in practice may now be dealt with.

1. *Removal of the Alkali.*—This is brought about by means of heavy irrigation and draining the water out. Considerable salt can be washed out in this way, and in one or more seasons the land may be fit to carry a crop. Even when there is no means of draining the water out satisfactorily, the large quantities of irrigation water serve to dilute the soil water in its alkali content and so to mitigate the evil to some extent. Of course the crop that can be grown under such conditions is only rice and moderately good crops can be raised if the soil is not very alkaline. If facilities for drainage exist, that is to say, if the land is not a dead flat but has a slight slope which will permit of an outlet being created, then the conditions are favourable for this method of reclamation, and not only can the evil be much mitigated but the improvement may be maintained at a fair level permanently.

2. *The Prevention of the Entry or Rise of Salts in the Soil and Drainage.*—This is accomplished by means of drainage. The cutting of drains of the necessary depth and systematic drainage reduces the level of the soil water and keeps it along with the salts in it below the root range of ordinary grain crops (and even of sugarcane) and at the same time secures a removal by leaching out of the salts in the drainage water. Drainage is the most satisfactory and effective method of solving the problem and it is only where it is not pro-

vided, or cannot be provided, on account of the situation of the land that the trouble cannot be overcome and only temporary and palliative methods have to be resorted to. To obtain the full benefit from costly irrigation schemes and to guard against a serious and progressive deterioration of the soil and in addition further in the interests of the health of the population, an efficient drainage scheme ought to go hand in hand with the irrigation scheme, and operated in an equally regulated manner. Drainage mains, sub-mains and field drains have indeed to be provided before the land is parcelled out, so that rights of individual ownership may not make such provision difficult.

A somewhat minor method which may be included in this category is to cut a deep drain across the line of flow of the underground water and so cut off the percolation of the salt-laden water into the cropped field. Such drains called 'cut-out drains' are dug parallel to the bunds of tanks or canals, adjoining the fields below them. Where surface wash from adjoining lands brings down any salt-laden water, similar protection should be provided by both cutting a drain and putting up a bund across the line of flow.

3. *Prevention of Seepage from Canals.*—A method of preventing the seepage of water and the rise of the level of underground water in the fields under channel irrigation which serves at the same time to conserve water-supply, consists in lining the bottom of the canals and their sides with impervious material like cement. Of course, this is a very expensive method but the outlay will perhaps be made up both by the saving in the water and by the mitigation of water-logging and alkali trouble. A less expensive method is reported to be the use of well-puddled clay kneaded with sodium carbonate, instead of cement. The material may be almost as impervious as the cement itself, but may prove only of temporary value requiring renewal frequently, as it is subject to the action of flowing water.

4. *Neutralisation of the Alkali and Improvement of the Physical Condition of the Soil.*—The application of manures and various other materials to the soil, which is another important method largely practised, has for its aim both neutralising or destroying the alkali and also the improvement of the physical condition, of the soil. These materials comprise firstly various manures, principally green manures, which are reputed to kill or 'eat up' the alkali, the alkali being partly consumed in acting upon and dissolving or disintegrating these materials. Although most green manures are useful in this way, some like Yekka (*Calotropis gigantea*) and Neem (*Melia azhadirachta*) are reputed popularly to be specially good in this respect. The chief action is probably more in the improvement of the physical condition brought about rather than in any such neutralisation. The soils are rendered more open and drainage is improved.

Heavy applications of farm-yard manure either by itself or in conjunction with sulphur are found beneficial, the effect being both chemical and physical in this case also. The dose which has been

recommended as best, in experiments in the Deccan canal tract (Bombay) is a mixture of 2 tons of farm-yard manure with $\frac{1}{2}$ ton of sulphur per acre.

Gypsum is an old and well-known neutralising agent for this purpose. Its effect is due to its reaction with carbonate of soda, which is now converted into sulphate of soda; this is not injurious like the carbonate.

The application of molasses comes in a class by itself. Molasses are recommended to be applied to ordinary cultivated soils almost as a manure, as it promotes the fixation of atmospheric nitrogen in the soil and thus leads to an increase of this important plant food in the soil. On alkaline soils, its action has been found to neutralise the alkali very materially. Considerable acidity develops soon after the application of molasses due to the formation of lactic, butyric and other acids, and on ordinary soils when used as a manure, a fair interval of time has to lapse before crops can be put in, so that the acidity gradually disappears. On alkaline soils, however, this is an advantage, inasmuch as the sodium carbonate is neutralised by the acids. The method is said however to rank next to the sulphur and farm-yard manure mixture mentioned above.

5. *The Renewal of the Soil.*—A favourite method in practice is to remove the top salty layer of the soil altogether; such scraping off of a few inches removes the layer in which the salt is most concentrated and thereby reduced the trouble very greatly. Instead of such removal of the soil or in addition to such removal, fresh soil (of course alkali-free) is carted to the field and mixed with the top soils. This has the effect of somewhat diluting the strength of the alkali in the field. Of course these are adapted only to small-scale cultivation; moreover it is only a palliative and the effect is temporary in character. The alkali continues to rise as usual and in a few seasons the top soil becomes too concentrated, again necessitating a repetition of the method.

6. *Growth of Vegetation.*—It has been found advantageous to have some vegetation growing on the land, which will withstand the alkali, if possible, and to make use of this expedient also as a method of reducing the alkalinity. In the Deccan canal experiments it was found that crops of lucerne and 'shevre' (*Sesbania ægyptiaca*) reduced the sodium content of the soil by quite two-thirds and one-half respectively.

7. Another important precaution is to keep the soil well tilled, ploughed or hoed during the time that there is no vegetation on the land. This has the effect of preventing the rise of moisture (and the salt in solution) into the top layers, and therefore preventing any increase or accumulation of salt therein.

Crops on Alkaline Soils.—While on soils which are excessively alkaline no crops or vegetation of any kind will grow, various plants show some kind of tolerance for alkalis, which depends upon the

degree of alkalinity and upon the kind of plants themselves. According to experiments by Dr. Leather, on Indian alkaline soils, as far as the extent of the alkalinity is concerned, about ·2% of sodium carbonate in the soil was found harmful to growth while ·4% was found fatal. The sulphate and the chloride were found to be less harmful than the carbonates, as already mentioned.

Among the crops which were tried, he found that Bengalgram and 'tuver' suffered most and that maize was tolerant, and that wheat withstood up to ·137 of alkali carbonate but failed at ·2%. In general the legumes were found to suffer more than the cereals. As cultivated crops for soils of moderate alkalinity, and under irrigation, rice is a suitable crop and there are also local varieties which are somewhat more resistant than others. Among other grains, ragi, *Paspalum scrobiculatum,* maize, barley and wheat may be put down as suitable in the descending order of tolerance. Among other salt-tolerant crops are sometimes also included beet, and some of the *Brassicas* like cabbages, knol-kohl, broccoli, etc. Among natural vegetation many grasses and "salt worts" are mentioned (as found in other countries) which are: Tussock grass (*Sporobolus ciroides*), Grease weed (*Sarcobatus vermiculatus*), Dwarf samphire (*Salicornia subterminalis*), Bushy samphire (*Allenrolfea occidentalis*), Salt wort (*Suœda torreyana*), Alkali health (*Frankenia grandiflora*), Cressa (*Cressa cretica*) listed by Hilgard. Among bushes, the prickly pear (*opuntias*) and among trees the wild date (*Phœnix sylvestris*) and the babul (*Acacia arabica*) can be found thriving on such soils in South India, while the cocoanut tree will also stand some degree, though much less, of alkalinity (for a further list see *Agri. Ledger,* 1901, pp. 68, 69).

Composition of Some Typical Indian Soils

	Moisture	Loss on Ignition	Insoluble residue	Nitrogen	Phosphoric acid	Potash	Lime	Magnesia	Iron oxide	Allumina
Indo-Gangetic Alluvium										
Sandy soil from near Cawnpore ..	..	1·07	91·72	·027	·08	·33	·35	·78	2·36	2·92
Sandy loams from Ison Ganges Doab	..	2·42	18·08	·081	·08	·64	·47	·32	3·10	4·38
do. Burdwan Expl. Farm	..	2·13	84·31	·042	·04	·56	·28	·66	5·58	6·09
Loamy soil from near Cawnpore ..	..	2·91	84·84	·046	·10	·16	·91	·52	4·52	5·30
,, ,, Patna ..	..	1·73	82·96	·045	·13	·66	1·78	1·53	4·59	5·11
Clay loam ,, Bahr, Patna ..	..	5·93	72·64	·051	·07	·82	1·01	1·64	7·58	9·89
,, ,, Dumraon Farm	..	2·24	80·90	·041	·08	·73	2·07	1·17	6·12	6·50
Calcareous soil from Pratapgarh (Oudh)	..	7·32	57·52	·180	·18	·44	14·54	1·86	3·23	3·39
Sandy loams from Thar Parker soil	·42	1·84	90·05	·043	·11	·19	·28	..	..	..
,, (Goradu) Gujarat ..	1·34	4·06	80·58	·056	·17	·502	2·6	..	..	..
Deccan trap deep black soil from near	..	19·2	63·8	·06	·23	1·60	1·90	..	..	..
Poona	..	11·66	55·7	·054	·10	·53	4·39	..	..	..
Typical black cotton soil West Khandesh	..	7·9 to	60·7 to	·042 to	·023 to	·13 to	4·5 to	..	..	..
,, soils, Dharwar ..	..	9·7	70·8	·053	·033	·19	6·2	..	..	..
Red laterite soil from Belgaum District	6·2	8·3	98·8	·11	·281	·270	·174	..	..	..
Red soils from Hubli ..	..	7·66	79·88	·03	·07	·62	·66	..	..	..
Areca garden soils from Sirsi ..	..	6·7	76·0	·15	·05	·44	·03	..	..	..
Coffee Estate soils (Red loams) from										
Kadur District, Mysore Soil ..	1·7	7·03	78·73	·165	·04	·31	·20	·44	3·52	7·72
Subsoil ..	1·6	5·72	78·43	·081	·028	·32	·21	·38	3·74	9·45
Hassan Dt., Mysore Soil ..	2·05	7·27	75·21	·154	·038	·39	·31	·32	4·79	9·36
Subsoil ..	2·13	6·38	73·79	·097	·027	·36	·31	·24	5·36	11·16
Coffee Estate soils highly ferruginous										
Kadur District, Mysore Soil ..	4·14	15·78	45·50	·303	·11	·26	·39	·59	16·42	16·65
Subsoil ..	4·08	13·26	46·97	·215	·11	·28	·32	·49	17·16	17·17
,, ,, Soil ..	3·02	13·73	55·75	·223	·10	·15	·23	·41	10·04	16·65
Subsoil ..	2·76	12·47	54·23	·126	·08	·15	·14	·41	10·10	19·95
Soil (sandy loam) Khurda Farm,										
Orissa (Good sugarcane land,										
overlies laterite bed) Soil ..	..	3·68	81·18	·074	·062	·50	·45	·42	12·75	
Subsoil ..	..	3·52	81·45	·060	·066	·59	·40	·40	12·77	
,, Cuttak Farm Sandy loam Soil ..	..	2·83	86·66	·004	·03	·24	·30	·59	3·74	5·52
Subsoil ..	..	3·08	84·33	·004	·03	·33	·39	·41	4·83	6·37
Leatrite soil, Ranchi ..	..	2·74	78·62	·039	trace	·43	1·5	·66	6·35	8·98

CHAPTER IV

THE MOISTURE IN THE SOIL AND ITS CONSERVATION

ALL plant life depends for its sustenance and growth on an adequate supply of water; in fact, as a factor of crop production, water may be said to take the foremost place and especially so in a country like India. Not only are all plant tissues in the green state composed mostly of water which may amount from 80% to 90% but they transpire very large quantities continuously during growth. The amount so used up by any particular crop may be reckoned on the average to be quite 300 to 400 times the weight of the dry matter built up. Such large quantities of water are required because plant foods can be taken up from the soil only in an exceedingly dilute state, and the assimilation, building up and translocation of the different plant products and substances of which the tissues are made up can also take place only in such very dilute solutions; in fact any circumstance which may increase the soluble constituents of the cell sap beyond this very low limit will result in scorching or other serious injury to the plant. An adequate uptake and circulation of water is also necessary for maintaining the turgidity of cells and tissues and for keeping the temperature about the plant surface sufficiently cool through transpiration and evaporation from the leaf surfaces. This continuous absorption of water in sufficient quantities and dilution for these different purposes is accompanied by the simultaneous giving off of all the large surplus by the process of transpiration and this accounts for the very large quantities of water required in proportion to the dry matter built up.

The soil is the source from which this very large quantity of water has to be derived by the crop and absorbed through the agency of its root system. It is doubtful if plants absorb any water from the rain or dew through the leaves or stems, though a certain freshness due to the cooling effect certainly accrues; but even if any moisture is absorbed it is negligible. It is from the soil and through the root system that crops have to obtain their supply of water.

HOW WATER IS HELD IN THE SOIL

The moisture in the soil exists as a film adhering by surface tension to the particles of which the soil is composed. The film can be only very thin and almost negligible when the moisture is very low, as in the case of ordinary air-dry soil, in which state the pore spaces are almost at their maximum and are filled with air. With an increase in the moisture content, the films grow thicker, the pore space becomes correspondingly less as likewise the amount of air within the soil. The water-absorbing rootlets of plants are in close contact with these moisture-holding particles of soil in between the

3

pores and take up moisture together with the plant foods contained therein. If the pores become filled with water and become blotted out, so to speak, the rootless of ordinary crops cannot exist in the saturated soil and therefore no absorption of moisture can take place. With a low moisture content therefore the pore spaces are comparatively open and with increasing supplies of moisture they gradually become full until both pore spaces and air disappear and the soil is saturated with water. It is usual accordingly to distinguish three phases in the moisture content of the soil, *viz.,* when (1) the moisture content is so little that the pore spaces are as open as they can be, (2) the moisture increases and the pores are partially filled to different degrees, and (3) the moisture fills pores completely. To these three forms of soil moisture the following names are given: (1) Hygroscopic, (2) Capillary, and (3) Gravitational.

The *'hygroscopic'* moisture is the moisture which exists in the soil when it is 'apparently' dry. When a soil well-dried in the air and looking quite dry, is exposed to a temperature of boiling water (100° C.) it will still lose moisture and the moisture so lost which can be driven off only by such drying at 100° C. is the 'hygroscopic' moisture. Obviously such moisture is of no use to plant life.

The *'capillary'* moisture is what adheres to the soil particles and partially reduces the pore spaces to varying degrees. This degree of moisture has a big range of variation, *i.e.*, between the hygroscopic percentage and the saturation percentage. It is the moisture which the crops make use of, and for satisfactory growth the percentage should not fall below a certain limit. Below this limit growth will be poor and at a particular limit still lower, actual wilting may begin. This wilting point is to some extent relative, because plants differ in their capacity to resist water shortage, which they do either by definite adaptation in structure or by their ability to send down roots deeper into moist layers of the soil. At this point in the moisture content of the soil, capillary though it is, it cannot be made use of by plants, the water being held too firmly to the soil, to the colloidal clay, as it is believed. This stage is capable of being measured and being numerically expressed. Where the supply of water can be controlled as in irrigated cultivation, it will be useful to know what the moisture content of the soil should be maintained at, for continued satisfactory growth and what the moisture content will be at the wilting point. Irrigation in respect of both quantity and of frequency can then be usefully regulated.

The *'gravitational'* water or moisture is that which exists in the soil at the stage when the ores are completely filled with water and more is held than what the surface tension can bear and therefore gravity acts and the water begins to leave the soil and descend down. With further additions of water by rain or irrigation it moves down until it reaches the level of the underground water (or water-table) increasing this level and helping the movement of this water to lower levels into tanks, streams and rivers, if such

movement is not impeded. Agriculturally gravitational water as such cannot be made use of by crops because the water shuts off the pore spaces and the air, in the absence of which roots cannot function.

Moisture-holding Capacity of Soils.—The quantity of water or moisture which soils can hold differs with different soils, depending upon the size of the particles of which the soil is composed. The finer the particles, the larger their number within in a particular volume and the greater therefore the surface of the film of water; such a soil will hold more water than one in which the particles are not so fine. The more sandy the soil in practice, the less water will it hold and the more clayey it is the more water it will hold, the loams of different kinds occupying intermediate positions. The amount of water which soils can hold is taken to be the quantity which will remain in the soil after the soil is first saturated and then allowed to drain until the drainage stops. The water-holding capacity of various soils can be easily determined in the laboratory by the above method.

The water-holding capacity of certain typical soils was found to be as follows:—

Coarse sandy soil from 15 to 31%, light loam about 22·6 to 33·5% and stiff clay soil about 36·1 to 49·6%. As the soil particles in a soil are not of any uniform size but consist of varying percentages of soil of different sizes, the values will largely vary with individual soils and the above are given only as examples. The ordinary red loam round Bangalore was found to have a capacity of 31·4%.

As already stated, not all the water contained in a soil will be available to the crop, nor will plants benefit to the same extent when the water has reached saturation point; the most favourable moisture content is that which will afford ample moisture and aeration to the roots. This is generally about 40% to 50% of the maximum water-holding capacity of the particular soil. On the read loamy soils around Bangalore this was found to be 12%, equivalent to about 40% of the total capacity of 31%.

The same quantity of water or rainfall will saturate a sandy soil sooner than a loamy or clayey soil and this accounts for sandy soils becoming soon saturated or almost water-logged, after even a moderately heavy rainfall which may be found quite insufficient on a loamy or clayey soil.

Gains and Losses of Soil Moisture

Not all the water which a soil may receive or contain can be available to the crop. A good portion of the water received by the soil is lost in various ways and is therefore not available to the crop. Some is lost by surface run-off, some through percolation of drainage, some through evaporation from the soil surface and some in other ways. It is the soil moisture which is left in the soil over and above

these losses that has to supply the large quantities required by the crop and this, it will be found, is only a small part of the water received by the soil. According to one estimate the moisture so available is put down only as 20% of the rainfall of the tract. It will be useful to consider the gains and losses somewhat in detail, especially in reference to the methods by which the one can be increased and the other can be reduced.

Gains to the Soil Moisture

The soil receives its water-supply through rainfall and by artificial irrigation. The subject of irrigation is dealt with separately and we may therefore confine the discussion to the moisture in the soil which is derived from the rainfall.

The gains to the soil come both from above and below. From above it is through rainfall (and snowfall in the northern latitudes). The gain of moisture through rainfall is the most important, but it may be largely offset by different factors. For example, if the surface of the country is very undulating and the fields lie on a slope, then much water may be lost by surface flow; the higher the field and the steeper the slope the greater is the loss. Such loss may be much intensified if the rain should come in bursts of heavy downpours. Small and insignificant showers occurring at long intervals on the other hand do not add to the gains, as the rainfall just moistens the surface without descending down and is readily lost by evaporation, except where a crop is standing on the field when even this will do some good. The loss by the slope is however the only factor which can be controlled by levelling, terracing, etc., which will be referred to later on.

The next method by which the soil gains moisture is from below, *i.e.,* by capillary rise, from saturated or nearly saturated layers of soil down below, much in the same way as the oil in a lamp rises in the wick, or ink or water rises and spreads in blotting-paper when it comes into contact with either. The force of capillarity enables the moisture to overcome the force of gravity and to rise into upper layers of the soil. Such rise will therefore depend upon the strength of this force, which in its turn depends upon the fineness of the soil (within limits); the finer the soil, the narrower are the pores and the stronger is the capillary force. It will also depend upon the evaporation and loss of moisture from above in the surface soil; but even here it is subject to much limitation, because if the soil becomes dry the rise will stop, although moisture rises by capillarity from a moist layer to a less moist layer. As a matter of fact, a soil layer quite dried out by evaporation will form an effective seal to the water in the soil below, even though this may be saturated. Normally and subject to the above limitation, the rise by capillarity makes a material addition to the soil moisture.

The height through which such rise can take place within a reasonably short time is however not much. In experiments in the laboratory (by the familiar method of standing long tubes containing soil in a trough of water and measuring the height to which the moisture rises) the following was observed :

In 24 hours the level rose 14" in one case and 18" in another case. The rise thereafter was very slow and reached 22" to 24" in three weeks. The soil used was the ordinary red loam round Bangalore. Experiments elsewhere too show that the rise by capillarity is very slow indeed.

Capillary rise is helped by compacting the soil, which is equivalent to reducing the size of the pores. A little tamping of a soil with moisture below will have the effect of bringing up the moisture to the surface. This is taken advantage of in practice when a soil is tamped or compacted by log or roller, which helps the seedbed to receive some moisture from below. On the contrary, the stirring of the soil amounts to a widening of the pores and hence reduces the capillary rise of moisture; this is made use of in practice to produce a soil mulch and reduce loss of water.

It is also to be remembered that capillary rise is favoured by the presence of some moisture in the top soil and that as already mentioned it cannot rise if the top soil is quite dry, just as a dry towel cannot suck up moisture as well as a moist towel.

Capillarity in Different Soils.—Such as it may be, the rise is much influenced by the fineness of the particles of which the soil is composed, *i.e.*, according as it is clayey, loamy or sandy, and in the last case depending upon the coarseness of the sand. The rise is generally quickest in the coarser soils than in the finer soils but in the latter it is highest.

In clay soils though the rise is highest there is always the risk of the clay shrinking and cracking and thereby stopping the further rise altogether. The rise moreover is much less rapid than in the sands and loamy soils. It is really in good loamy soils that the gain through capillary rise will be material enough to be of benefit to the crop.

With a crop growing on the land (or plant growth of any kind including weeds) the drying effect due to the absorption and transpiration of moisture by the crop is very great and extends to a great depth, even though the roots do not extend deep at all. The loss of water by actual contact of the moist soil with the rootlets being thus excluded, one has to infer that the moisture has risen only through capillarity which is thus seen to act through a greater depth than may be supposed. In experiments on the soil moisture movements conducted in Bangalore, one of the plots was under Bengalgram and the moisture content percentage of the soil up to a depth of 6' before sowing the crop and when the crop was two months old, was as below :

Depth		Bengalgram plot	Soil cultivated 1½ in.	Soil cultivated 1½ ft.	Left uncultivated
0″ to 1½″	..	1·02	1·77	1·92	1·60
1½″ to 3″	..	2·47	4·81	4·54	2·93
3″ to 4½″	..	3·92	4·95	5·56	3·90
4½″ to 6″	..	2·96	6·31	6·82	4·56
6″ to 7½″	..	3·85	7·62	8·51	7·76
7½″ to 9′	..	6·89	..	..	..
9″ to 1′	..	8·71	8·79	9·04	9·17
1′ to 1′3″	..	8·98	11·58	10·82	10·04
1′3″ to 1′6″	..	9·04	12·70	12·44	10·24
1′6″ to 1′9″	..	8·30	12·12	12·89	11·57
1′9″ to 2′	..	8·54	12·19	12·37	11·89
2′ to 2′3″	..	9·46	11·62	12·46	11·8
2′3″ to 2′6″	..	8·91	12·11	12·66	11·94
2′6″ to 2′9″	..	9·16	12·39	12·77	12·06
2′9″ to 3′	..	8·94	12·45	12·86	11·83
3′ to 3′6″	..	8·75	13·04	13·08	11·91
3′6″ to 4′	..	0·22	12·93	12·47	12·52
4′ to 4′6″	..	9·73	12·94	12·95	12·82
4′6″ to 5′	..	10·30	13·09	12·95	12·94
5′ to 5′6″	..	10·64	12·13	12·56	12·40
6″ to 6′	..	10·11	11·23	12·35	12·83

The moisture content of the above soil at the beginning of the experiment was as below :—

Depth		Moisture % at beginning of experiment
0″ to 6″	..	10·22
6″ to 1′	..	12·15
1′ to 1′6″	..	14·20
1′6″ to 2′	..	14·68
2′ to 2′6″	..	14·72
2′6″ to 3′	..	14·60
3′ to 3′6″	..	14·55
3′6″ to 4′	..	14·77
4′ to 4′6″	..	14·67
4′6″ to 5′	..	15·02
5′ to 5′6″	..	14·85
5′6″ to 6′	..	14·69

(Page 58, *Eighth Annual Report of the Mysore Agricultural Dept.*)

This aspect of the capillary rise of moisture is even more important from the point of view of loss of soil moisture and the methods of conservation and is referred to further on.

It is also interesting in this connection to note that in certain parts of Mysore, the belief is very general that the growing of casuarina groves depletes the subsoil water to great depths and that the

water-table has gone down greatly, with the result that wells have to be sunk very much deeper now than formerly, when the cultivation of these trees was not so extensive. This is a frequent complaint by farmers in these tracts and even Government is often petitioned that the growing of casuarina topes in cultivated areas should be forbidden.

Losses of Soil Moisture

(*a*) *Surface Flow.*—The most serious loss of moisture takes place through surface flow or run-off from the surface. This has already been referred to and will be dealt with again in connection with soil erosion and methods of preventing it. It may be mentioned, however, that the run-off from many Indian soils has been measured and been found to amount to even 76% of the rainfall, the lower limit in this series of trials being 21% (A. T. Sen, *Ind. Jour. Agr. Res.,* June 1946). Around Bijapur (Mysore), the loss by run-off was found to vary from 30% to 40%, while in Hagari (Bellary) it was found to be 50%.

(*b*) *Percolation or Seepage.*—The soil water keeps continuously moving down under the influence of gravity and all water which is in excess of what can be held by the particular soil percolates or drains away lower down provided it is not prevented or obstructed by impermeable rocks or other strata. Such percolation is largely helped by the nature of the soil, the more sandy and large-pored the soil the more is the seepage; the more clayey and impervious it is the less is the seepage. Percolation is also influenced by the lie of the land, whether it is flat or basin-like or has a slope small or great. Percolation may be hindered by the occurrence of impervious soil pans or hard rocks or by the situation of the land itself. These are, however, cases where the condition is one of accumulation of water instead of being a loss of water, and such conditions have to be corrected by methods of drainage, as they are greatly harmful to crops (see under Drainage).

Loss by excessive percolation in soils have to be corrected by the addition of clay or tank silt or by well-decomposed bulky manures like cattle manures to such soils. In the hot weather it is usual to dam up drainage trenches, as the need for moisture is great and the trenches may favour loss through drainage.

In a country like Mysore, which is situated on a plateau and is traversed by an endless series of hills and valleys, there is a gradual movement of the underground water both vertically down and laterally towards the tanks and other hollows or lakes and watercourses. The level of the zone of underground moisture fluctuates with the level of the tank or lake in the hollow, though it maintains a much higher level and follows the contour. The level of the water in wells in such situations reflects this tendency except where rocky pockets or strata intervene and cut off the flow.

The rate of percolation and loss of moisture from that cause has also been measured under the soil conditions of certain stations in India. Such figures are available for the soils of the Indo-Gangetic alluvium in Cawnpore and in Pusa, where these studies were conducted by properly constructed 'drain-gauges' or 'lysimeters'. The loss by percolation on these soils was found to be very great and to be influenced by the rainfall very much. Thus, in the 6′ gauge with a crop of wheat growing on the soil the percolation loss averaged 2″ to 3½″ of rainfall; with a rainfall of 40″ to 50″ the loss rose to between 9″ and 13″, with a rainfall of over 55″ it rose to 15″ to 20″, the highest loss being 24·4″ with a rainfall of 62″. In the 3′ gauge the loss was 5·2″ to 8·8″ for a rainfall of below 40″ and 12″ to 13″ for a rainfall of 40″ to 50″. This is probably more important as the 3′ depth is more material for ordinary grain crops. Vegetation on the land reduces the loss very materially and in the above experiments when there was a crop of sannhemp on the land the loss was reduced on the average by 35% (Abhiswar Sen, *Ind. Jour. Agr. Res.*, XIII, V).

(*c*) *Evaporation and Capillary Rise.*—The drying effect of evaporation is a potent cause of the loss of soil moisture. The high atmospheric temperature generally prevalent in India especially in the hot weather months when the soil lies fallow, the high and persistent winds also peculiar to this season and the high temperature of the soil itself, all conduce to a rapid and serious drying out of the soil. Average temperatures up to 105° F. are common on the plains in South India while still higher temperatures up to 115° F. rule in Upper India. On the plateaus and hills, temperatures are not so high but even here the maximum may go up to 90° F. The temperature of the soil surface in the black cotton soils may go up to 69° C. (Poona) as a maximum while in the red to light red soils to 65° C. and on the ashy grey soils (Pusa) to 40° C. Both these causes add to the evaporative effect of the atmospheric temperature. It has been found however that the effect of the wind in this respect is more than that of the temperature. As the evaporation increases with an increase in the surface exposed to such evaporation, a ploughed, hoed or stirred up surface dries more quickly than an undisturbed surface. Inside of a standing crop however both temperature and wind velocity are greatly checked and the drying effect of evaporation is therefore largely reduced; obviously this saving effect has a bearing only in irrigated cultivation as the drying effect of a crop itself is far in excess of the reduction it may effect by checking evaporation.

Depth of Drying Effect.—The depth to which the drying effect can extend and the possibility of preventing such drying out are obviously very important in practice. Drying extends downwards directly through deep cracks which develop in clay soils and in the black cotton soils when the deeper layers come directly into contact with the hot wind.

Indirectly the drying of the top soil may lead to a greater pull by capillarity of moisture from below, but it is difficult to say to what depths this may extend. Soil moisture experiments in Bangalore show that it may extend to a depth of even 5′ to 6′. The fact of practical importance is that if the top soil becomes quite dry, either as a soil mulch or as a hard compact layer, the capillary rise seems to stop completely and no further loss of moisture takes place from below. The hard dry soil seems to act as an effective seal as already stated.

Thus in a soil in which the underground water was only 1′ 7″ below, the moisture content in the upper layer was as follows :—1·94, 2·07, 3·63, 4·47, 7·57, 9·42, 10·95, 11·77, 12·55, 13·26, 13·80, 14·10, 14·90, 15·05 respectively in 1½″ sections from the top right down to the level of the water-table.

On the black cotton soil (Poona) it was found that once the top soil became quite dry, there was no change in the moisture content of the lower layer up to 18″, and such loss and gain as accrued to the top soil was only on account of the diurnal variation and the top soil gained a little moisture during the night from the atmosphere and lost it during the day.

As the result of certain soil moisture determinations in Bangalore, it was found that the effect due to the loss of water by evaporation did not extend to more than 1′6″ in either of the cultivated plots (one plot cultivated 1½″ deep and another 1½′ deep) ; but in the uncultivated plot it probably extended to about 2′ 6″ depth and possibly further than that (*vide* table on page 70).

On the whole it may be said that the rise of water through capillarity is too slow to be of material benefit to crops except where the roots may reach to almost 2′ or less of the level of the underground water. It may be added that recent work throws doubt on the upward capillary movement of soil moisture to the extent or degree, commonly believed.

Conservation of Moisture by Cultivation.—That the loss by evaporation can, to some extent, be reduced by keeping the top soil stirred or cultivated admits of no doubt; it is however not possible to say what the extent of this saving will be and to what depths it may extend. According to the Bangalore experiments, the saving as against soil kept uncultivated was very small, being the equivalent of ½″ of rainfall during a period of 4 months and could not account for the benefit which the crop derives from a frequent stirring of the top soil. Whether much saving can be effected in the lower layers of the soil by leaving the soil in a ploughed condition or at least stirred or cultivated to a small depth of a few inches is a question of much practical importance. The effect on the succeeding crop (of ragi) raised on such a soil has been striking, as higher yields have been obtained on such fields than on fields left undisturbed. Based on this result, the practice of ploughing the fields after harvest has been recommended as an important dry farming practice. Such a result may be due to a saving of soil moisture or to other factors.

The saving in the soil moisture even at its best has been found to be too little to account for such a higher yield. It is possible that the soil may have absorbed more rain on account of its ploughed surface and that other changes, both chemical and bacterial, may have operated. It is thus a case more of direct addition of soil moisture through the rainfall than of conserving of what was already present in the soil.

(*d*) *Loss by Transpiration through Weed Growth*.—The growth of weeds (or other plant growth) is a very powerful factor in causing loss of soil moisture. It may be almost said to be the most serious among them. Figures have already been given which show what great depletion of moisture can be brought about by even a small crop of Bengalgram. Weeds (or crops) with a deeper and more extended root system and of better growth will cause a very serious loss of soil moisture. Hoeing and other forms of intertillage in crops bring about a saving of the moisture as much through the destruction of weed growth as through the protecting effect of the soil mulch, a factor to which the great saving in moisture was long believed to be largely due. The stirring of the soil and destruction of weeds whether prior to or during the crop season, has to be continuously attended to, in order to keep down weeds and the loss of moisture through them.

(*e*) Under certain circumstances the same moisture content may prove available or non-available according to the nature of the soil. In clay soils especially although the moisture content may appear sufficient still plants may not be able to utilise it on account of the fact that the moisture is held too fast by the clay particles to be withdrawn by the roots. A loamy soil, on the other hand, with the same moisture content will be able to maintain the growth without wilting setting in.

Moreover moisture in badly drained situations is often as bad as no moisture at all, because plant roots under these conditions cannot penetrate into the undrained soil, absorb moisture and function and will therefore begin to sicken and die, a short of starvation in the midst of plenty, to which the name "physiological drought" is given. In these two cases there is of course no loss of soil moisture but only a kind of locking in, which puts the moisture out of the reach of crops.

Conservation of Moisture by Mulches.—The stirred top soil acts like a protective cover to the soil, preventing or reducing loss by evaporation definitely but somewhat indefinite in degree and depth. It is common observation that under a covering either of stirred soil or any other loose material like a heap of dry leaves, for example, the surface of the soil is distinctly moist while near about on soil not so covered, the surface is quite dry. This property of a covering of this kind has to be taken advantage of in order to conserve soil moisture. Such protection can be afforded not only by loose soil, but also a number of other materials like a layer of straw or dry

leaves, arecanut husks, cut grass, heaps of cattle manure, bagasse or any similar coarse material like a heap of rags, or wool waste and even by stones. To these materials used in this manner the name "mulch" is given and when this is formed by loose soil it forms a "soil mulch". The most outstanding saving in moisture is brought about within very short distances from the surface and almost on the top soil itself. In the West Indies, we are told, that sugarcane fields are systematically mulched for this purpose by carting Guinea grass from long distances and spreading it over the surface between the rows of cane after irrigation. In the orchards of California huge quantities of straw are used for this purpose and after a heavy irrigation a thick layer of straw is spread round the base of the trees. It is not unusual in South India to see that a layer of coarse pebbles or road metal is spread around the bases of coconut trees, fruit or ornamental trees or shrubs in gardens, in order to keep the surface below this stone 'mulch' moist and to avoid the need for frequent watering. While many different materials can thus be made use of, in practice and in ordinary dryland cultivation the 'soil mulch' is the cheapest and most convenient.

The action of the "soil mulch" produced by ploughing or hoeing the field is two-fold. Firstly, it is the prevention or reduction of loss by evaporation as above mentioned. Secondly, it is the indirect but far more powerful action which it brings about by the destruction of weeds. It is now held that the stirring of the soil is important only from this point of view, *viz.*, because it destroys weeds, and that the protection by mulching is hardly material. In practice, it makes no difference how it brings about the saving, or in what proportion one is to the other, as it effects both results simultaneously; the one indeed cannot be separated from the other.

CHAPTER V

MICRO-ORGANISMS IN THE SOIL

THE soil is not an inert mass of dead material but teems with life of many kinds, from lowly bacterial life to various higher forms, most of which are invisible to the naked eye and may be classed therefore as the micro-organisms of the soil, and others which are larger and visible forms. All of them play an important part in influencing the soil as a medium for the growth of crops and their life is also considerably influenced in turn by the various tillage and cropping methods involved in practical agriculture. Most of them are helpful in agriculture but there are also some which are very harmful and are the causes of various crop diseases and are therefore detrimental to agriculture. We shall now deal briefly with such of the micro-organisms as are agriculturally important.

I. BACTERIA CONCERNED IN THE BREAKING DOWN OF CARBOHYDRATES

These are of two kinds: (1) one functioning only in the presence of oxygen, and (2) the other which functions in the absence of air or oxygen. Both kinds act upon all kinds of carbonaceous or organic matter, like vegetable or crop residues in the soil such as dead roots, stubble, dry stems and leaves, etc., cattle manure, animal matter of all kinds, etc. The bacteria reduce them all into a kind of powdery mass of disintegrated material and give off carbonic acid in the process, the carbon being derived from the carbon compounds of the wood or cellulose, or animal matter and the oxygen from the air. The oxidation may not be complete and the partially decomposed material will furnish the humus and other humic compounds in the soil. All these go to enrich the soil, principally improving its physical condition and incidentally adding also to the store of available mineral plant foods. All manner of vegetable debris, however hard and bulky, becomes eventually reduced to this condition by the action of these bacteria. Not only air but also a certain amount of moisture and of nitrogen in the material is necessary for the proper functioning of the bacteria and if these are lacking then the action can be promoted by furnishing them with these requirements. Usually, however, in nature and under farming conditions these are present to the degree required more or less, and there is no need for artificial aid. One point however should be noted, *viz.*, that the ratio of the nitrogen to the carbon has an important bearing and that this should be generally in the neighbourhood of one-fifteenth to one-twentieth for satisfactory results.

Special note has to be made of the fact that these bacteria are largely concerned in the conversion of the raw farmyard manure, consisting of both the liquid and solid excreta together with the large

quantities of straw and other waste material, from this form into the well-rotted waxy homogeneous material which is so much prized by the farmer.

2. The second kind of this type of bacteria is anaerobic or is able to function in the absence of air (or oxygen), such as under water-logged or marshy conditions of soil or when manure is packed too hard and tight and air is excluded. The raw material under these conditions is not oxidised wholly into the ultimate product carbon dioxide but the decay involves the production of intermediate products like marsh gas and hydrogen in addition to carbon dioxide. The residual compounds are richer in carbon, humus is largely formed and peat and even coal-like bodies with the lapse of time. They play an important part in the decay of ordinary farmyard manure also, in which as ordinarily stored both aerobic and anaerobic conditions exist, and the physical condition, and the chemical composition are both the net result of the action of both kinds of bacteria.

Attention may be drawn to a rather interesting application of this process of anaerobic fermentation, which consists in utilising these bacteria for the production of fuel gases from farmyard manure. Reference need hardly be made to the colossal waste of manure which is involved in the burning of dried cattle dung as fuel, which is so universal in India and which can be prevented only by providing the people with some alternative fuel in sufficient quantities and at a cheap price. If the farmyard manure can be fermented anaerobically and under control, then it can furnish fuel gases like hydrogen and marsh gas (as explained above) out of its carbonaceous portion, the nitrogen in the manure being left practically untouched and therefore available in the residue and not wasted as when manure is burnt. The method opens up the possibility of retaining the principal manurial content or plant food, *viz.,* nitrogen and at the same time providing the fuel (gas) for which alone the stuff is burnt at present. It is reported that the idea is being followed up and that its practical application on a commercial scale is being attempted.

II. Bacteria Concerned with the Fixation of Atmospheric Nitrogen

These bacteria are able to fix the free nitrogen gas present in the atmospheric air into the soil, that is to say, are able to utilise the nitrogen of the air for the building up of their bodies, which by their enormous numbers add to the nitrogen content of the soil. There are two classes of bacteria which both bring about this result; one of them is a free-living type and another is a type which lives in association with or leading a 'symbiotic' life with leguminous plants. The latter therefore cannot fix nitrogen except in the presence of a leguminous crop in the soil.

(*a*) *The Free-living Bacteria* (*Azotobacter*).These bacteria have the power in the presence of air to obtain the nitrogen required for building up their bodies, from the free nitrogen of the

atmosphere. The carbon required is obtained from the carbohydrates present in the soil or which will have to be added for this purpose and the energy is derived from the oxidation or burning up of the carbon. The nitrogen so taken up and stored in the shape of the millions of bacteria which multiply under such conditions adds to the supply of nitrogen (now fixed as a compound) in the soil. A definite relation has been established between the carbon oxidised and the nitrogen fixed, the ratio being 100 parts of carbon to 1 part of nitrogen fixed. The nitrogen so produced by this kind of bacterial life accounts for the moderate crop-producing power of even soils which receive no nitrogenous material of any kind as manure, crop or animal refuse, and in a sense, for the natural recuperation of soils. Any process or method which brings about a large multiplication in the numbers of these bacteria in the soil, will be the means of increasing the nitrogen content of the soil to a corresponding extent. A practical application of this method of fixation has been suggested in India (by Prof. N. R. Dhar) by the utilisation of sugarcane molasses as manure. It is claimed that by using molasses as the carbohydrate source of energy for the bacteria, this bacterial fixation of nitrogen can be very largely increased, and especially so in the presence of sunlight. An application of molasses at the rate of 3 tons per acre is reported to have added 112 lb. of nitrogen and at 10 tons to the acre to have added 270 lb. of nitrogen, to the acre.

At one time some years ago a similar attempt was made to increase the fixation of nitrogen in soils by manuring them with a preparation called 'Humogen', which was put out by W. B. Bottomley. The material consisted of peat which was first neutralised, then allowed to partially decompose by bacterial action, and after sterilisation was inoculated with nitrogen-fixing bacteria.

(*b*) *The "Symbiotic" Living Bacteria* (Bacillus radicicola) *which Fix Atmospheric Nitrogen.*—The second kind of nitrogen-fixing bacteria are not free living like the first kind but require a suitable living host plant in association or symbiotically with which alone they can function. These plants must belong to the leguminous order and this is a most interesting fact and one most important in its application to practical agriculture. These bacteria enter into, reside and multiply in the roots of all leguminous plants, in which they form small nodule-like swellings, varying in size from a mustard seed to a pea. The bacteria depend upon the leguminous plant for carbohydrates which are absorbed from what the plants produce, and upon the atmospheric air for their nitrogen, which they have the power of taking up. The nitrogen so taken up and built up into their bodies forms the all-important nitrogenous plant food for the host plant, so that the bacteria and the plant are mutually helpful and dependent—a form of existence to which the epithet 'symbiotic' has been applied. The more numerous the nodules, the greater is the fixation of nitrogen through the bacteria and the better is the growth of the plant.

It is only the plants of the leguminous order that can utilise the nitrogen of the air in this manner with the help of these bacteria and can flourish and make good growth, even though there may be no nitrogenous plant food supplied in the shape of manure, or naturally present in the soil. It must be pointed out, however, that like plants of other orders the legumes can also make use of soil nitrogen and if the bacteria are not present in the soil or if the conditions are not favourable for the functioning of the bacteria, then legumes like other plants must depend on the soil nitrogen itself and what may be added as manure for meeting their requirements of nitrogen. If the supply in this way is lacking, then their growth will be poor just as in the case of other plants. It is, therefore, essential for the fixation of nitrogen by the legumes, firstly, that the soil should contain these bacteria and secondly, that other conditions should be favourable. These conditions are that other plant foods such as potash, phosphates and lime should be present in adequate quantities and other ordinary conditions for plant growth, *viz.*, aeration and the necessary moisture content. If these conditions are fulfilled then bacterial activity will be vigorous and nodule formation which may be taken as an index of such activity abundant and nitrogen fixation therefore satisfactory.

It is also to be pointed out that each particular legume has its own particular strain of nodule bacteria and unless that particular strain is present in the soil its host legume will not flourish or take up nitrogen from the air. Whether this applies to every one of the numerous kinds of leguminous plants that are to be found in nature or to particular groups or whether some can adapt themselves to a different strain eventually, are matters not definitely known, but in the case of all the legumes ordinarily cultivated, this limitation applies.

The difficulty can be got over in practice by *'inoculating'* the soil with the particular bacteria peculiar to the legume proposed to be grown; pure cultures for this purpose are sometimes available for sale and suitable instructions accompany the packets, as to the method of applying the cultures to the soil. Much the same effect can be produced by the simple method of bringing a cartload of soil from any field on which the particular legume has been known to grow well, and then spreading it over the field to be treated. This is tantamount to inoculating the soil and the method is simpler than that of using pure cultures. Of course, this will not be possible when the legume proposed is new or not grown anywhere near enough for carting the soil.

It will thus be seen that the growing of legumes is one way of adding to the store of nitrogen in the soil or of dispensing with the need for that quantity of nitrogen in the shape of manure. A leguminous crop grown on soil poor in nitrogen but well provided with the particular bacteria and with the plant foods other than nitrogen can be expected to develop nodules abundantly and to make very good growth. All the nitrogen which has gone into the composition of the tissue of the crop, both above and below ground, has come

from the atmosphere and if the whole of the crop should be incorporated with the soil, then all this nitrogen is a distinct addition to the soil, just as though it was manured with that quantity of nitrogenous manure. If, however, the above ground parts, either whole or only the produce, are gathered and taken away, then the addition to the soil will be much less. But even then, what is left in the shape of the stubble and roots cannot be considered insignificant.

Some of the famous Rothamstead experiments in which clover or beans forms part of the rotation, have shown that not only a very much larger quantity of nitrogen is removed in the shape of the crops than is supplied in the shape of manure (including the nitrogen naturally present in the soil) but that the soil itself is left richer in nitrogen than it was at the start of the experiment, showing that large quantities of nitrogen should have accrued to the soil by the growing of the legumes. Some further aspects of this subject are dealt with under Rotations, Manures and Mixed Cropping (*vide* the respective Chapters).

III. The Nitrifying Bacteria (Nitrobacter and Others)

This class of bacteria bring about the conversion of complex nitrogenous compounds of vegetable or animal origin into simple inorganic nitrates. The nitrogen in the former form is not one which plants can take up and utilise whereas in the latter form of nitrates all kinds of plants can utilise it (puddle grown rice being the only important exception). These bacteria, therefore, may be said to convert non-available nitrogen into available nitrogen. The process is one of progressive oxidation, and is carried out in stages, the main intermediate one being the formation of ammoniacal compounds and the final product being the nitrate itself. The formation of gaseous nitrogen and of nitrous acid should also be included, but the change from the ammoniacal to the nitrate is too rapid to make these of much consequence, although they should be reckoned with and cannot be altogether ignored, for the formation of gaseous nitrogen means a loss of a valuable plant food and that of nitrites serious because it is poisonous to plants.

The nitrifying bacteria may be said to be most important agriculturally, as nearly all nitrogenous manures (with the exception of potassium and sodium nitrates) contain the nitrogen in a non-available form and have to undergo nitrification before they can be made use of by plants. Farmyard manure, the various oilcakes, guano, bloodmeal, bonemeal, fish, etc., and sulphate of ammonia and the various ammonium phosphates, urea, cyanamide, etc., have all to nitrify before they can be availed of by plants and exert their action in increased crop production. Nitrification takes place at varying rates from the different manures and fertilisers, the quickest being sulphate of ammonia or other ammonium compounds. Their rapidity of effect on the crop as manure will depend upon the rate at which they nitrify in the soil.

This will depend not only on the nature of the material itself but also on the soil conditions. The conditions which are favourable to nitrification and which should be provided in order to promote it are: (1) full aeration such as will be provided by ploughing and other forms of tillage, (2) an adequate quantity of moisture, (3) a sufficiently high lime content in a form which will react with the nitric acid, as it is formed by nitrification and combine with it. The lime content becomes specially important in the case of ammonium sulphate so that it can combine not only with the nitric acid but also with the sulphuric acid, which latter will, in the absence of lime, make the soil increasingly acid in reaction.

It is also a noteworthy fact that the presence of a crop on the soil keeps down or reduces the quantity of nitrate produced as against soil not so occupied and lies fallow. More nitrate nitrogen is found on fallow land than on cropped land under the same conditions; this is not due merely to the fact that the crop is taking up the nitrate as it is formed, the fallow land is found to contain more nitrogen even after making allowance for this utilisation. The total of the nitrogen in the soil at start *plus* the nitrogen taken up by the crop is found to be less than what is contained by the fallow land at the end of the experiment. The practical bearing of this interesting fact is that the field has to be kept thoroughly free of weed growth when it is fallow, a fact which has to be stressed from the point of view of the conservation of soil moisture also.

IV. The Denitrifying Bacteria

In the absence of oxygen owing to the exclusion of the air, whether in soils or manure, nitrates are reduced back to nitrites and even to gaseous nitrogen progressively by another class of bacteria, *viz.,* the denitrifying bacteria. The nitrites are positively poisonous to plant life and the evolution of gaseous nitrogen is a waste of a most valuable constituent. Obviously, therefore, every effort has to be made to see that the conditions do not favour the increase of these bacteria. In practice, this means that soils should be prevented from becoming ill-drained, water-logged or insufficiently aerated, and that manures likewise be protected from such conditions. In the preservation and storage of farmyard manure, such aeration has to be regulated in order to prevent other changes taking place too rapidly and the manure being heated up and loss ensuing; something like a balance has to be struck between the provision of too much and too little aeration.

V. Other Soil Bacteria

Among other bacteria in the soil which have some agricultural importance may be mentioned the class which can oxidise elemental sulphur into the oxides, giving rise to the formation of sulphuric acid, with the production of sulphates in combination with the bases present in the soil. Advantage is taken of this process in trying to

convert bonemeal or finely ground rock phosphate into available forms of phosphoric acid, by mixing these with flowers of sulphur and ordinary soil and keeping the mixture in loose heaps, for several months. Considerable sulphuric acid is produced by bacterial action on the sulphur during this period, which brings about a certain amount of solubility in the phosphates added.

All the different kinds of bacteria described above with the exception of the denitrifying bacteria are distinctly beneficial to crops and are indeed so indispensable that their growth has to be promoted in all possible ways. It is reported that in order to increase fertility through intensive bacterial action, a new bacterial fertiliser called 'phosphoro-bacterin' has been put out in Soviet Russia and been found to markedly increase yields. Indeed, the fertility of soils itself is sometimes measured by the degree of bacterial activity (as indicated by the quantity of carbon dioxide evolved) which it can develop.

Other Organisms in the Soil

(*a*) *Soil Fungi.*—Among other micro-organisms in the soil are fungi of various sorts. Some of these attack and live upon dead plant tissue like dead wood and stems and in doing so reduce them to a powdery and partially decomposed condition favourable for use as humus-like organic matter in the soil. Though invisible to the naked eye in the beginning they make themselves conspicuous at the fruiting stage, when the fructifications appear in characteristic forms and are very readily seen.

Many other fungi are pathogenic and are the causes of many serious crop diseases to which the root systems of crops are subject; these are the various stump rots, root rots and "wilts" which are very difficult to combat.

(*b*) Soils also contain other micro-organisms important in agriculture which are somewhat higher forms like the protozoa. It is held that some of these are detrimental to the growth of the nitrifying and other beneficial types of bacteria in the soil, as the latter are kept down and their action inhibited when the protozoa increase. The reason for many soils, especially 'hot-house' soils, becoming 'sick' and unfit for certain crops is believed to be the increase of such protozoa. Sterilising the soil by heat or disinfectants is a method of curing such soils and this is brought about by the destruction of the protozoa in the process. Whether the beneficial result of sterilisation is really due to this cause is, however, a point not quite free from doubt.

It is now known that many of the soil organisms, and especially fungi, secrete as their life products chemical substances which are destructive of bacteria of certain kinds and of other organisms. The most remarkable and now well-known example is the drug, penicillin, which is the product of the familiar green mould called *Penicillin notatum*, whose power of destroying pathogenic bacteria of many kinds has found most beneficent application in modern medicine.

The soil is the home of many such organisms and their respective proportions and activities are the resultant of their ability to resist and survive the action of each other's 'antibiotic' secretions.

Somewhat higher in the scale come the eel-worms (helminths) which are positively harmful to crops. In some cases the growing of particular crops on fields infested by them becomes impossible; in other cases much weakening of the crops is brought about and even various malformations in the roots and root crops, such as swellings, blisters, knots, etc., develop. These are very difficult to combat by direct measures, although some machines for the heating of the soils by steam are reported. Only indirect methods like rotation of crops (applicable of course only in the case of annual crops and not plantation crops) will afford relief.

The soil is the home of many forms of higher life but these cannot be classed as micro-organisms, and cannot therefore be dealt with here. Some have however been referred to in appropriate places (*vide* Chapter on "Protection of Crops").

The practical implications of the various aspects of the life and role of these bacterial organisms consist mainly in the supreme importance which should be attached to various cultural practices, which, in addition to their other functions, serve the purpose of promoting the growth of the beneficial organisms and of suppressing the growth of the harmful ones. These practices comprise, thorough tillage at the correct stages, aeration, provision and control of moisture, drainage, the addition of lime, rotation of crops and the inclusion of legumes therein, and others which are dealt with in the different chapters.

CHAPTER VI

IRRIGATION

In tracts which depend solely upon the rainfall and where only dry-land cultivation is possible or practised, crop raising is always precarious; yields are low and uncertain, total failures are not uncommon, returns are poor for the money and labour expended and larger areas have to be farmed for securing even these returns. For assured food supply and profitable farming and the economical use of land, irrigation is indispensable and no amount of skill and knowledge will avail with dry cultivation alone. Moreover, dry cultivation can be carried on in one particular season alone, save in tracts favoured by both monsoons in India, and both land and labour will have to be idle during the remaining part of the year. When irrigation is provided both can be put to profitable use throughout the year, and yields can almost be doubled and more valuable crops can be grown and the money return increased still further. For these reasons, it is of the utmost importance that every agriculturist should try and secure for himself some source of irrigation, however small it may be, so that on at least a smalll area an assured crop may be obtained. From the point of view of the larger interests of the country, a large extension of irrigation is urgently called for in order to feed the steadily growing population with home-grown food and to avert the famines which occur almost every year in some part of the country or other.

Sources of Irrigation

The sources of irrigation are two, *viz.,* (1) surface water, and (2) underground or well-water.

1. *Surface Water.*—Surface water for irrigation is provided by the flowing waters of rivers and from the still waters of tanks or reservoirs, both small and large, in which the surface flow is artificially impounded in suitable sites. The irrigation water from these sources is carried to the fields by the mere flow due to gravity and is therefore cheap, but on the other hand it is not under all such sources that water may be available all through the year. Irrigation from rivers is mainly through canals drawn from dams across the rivers, which bring the water directly on to the fields. All the great irrigation works of India belong to this type. Irrigation from these is only seasonal, *i.e.,* during the flood season. When, however, the dams are of such a height that large reservoirs are formed, then water may be available both in the flood season and in the hot weather. It is only for the construction of such large dams that there is scope at the present time as all the dams that could be erected with the resources known in the old days have already been constructed. Innumerable tanks form an important source of

irrigation; most are rainfed but some are supplied in addition from river channels. A large number of tanks lie in a series along the valley line, surplus water from the higher tanks filling the lower ones, which overflow in their turn into still lower ones and so on down in line of drainage of the region. It is doubtful if there is scope for any extension of this type of tanks; the need and scope are, however, for the improvement of the existing ones. It has been suggested as a measure of erosion-control that streams and gullies higher up the valley should be dammed up likewise, but this will mean a reduction of supplies to the lower and more important ones.

2. *Underground Water.*—The subterranean supplies, on the other hand, can be tapped only by the digging of wells, shallow or deep, and sometimes very deep, and the water has to be raised by appropriate methods above ground for irrigation, all of which make it costly. The water-supply is moreover always available and irrigated cultivation will accordingly be possible throughout the year. Exceptionally, wells may be of the 'Artesian' type, tapping water-laden strata under pressure from which water may rise to or even above the surface without the need for water-lifts of any kind.

Wells have however the advantage that they are within the means and capacity of individuals to construct and operate, unlike tanks and other large irrigation sources. There is unlimited scope for the extension of well irrigation throughout the country. Wells may be either the sole source of irrigation or merely a supplementary source situated in areas already protected by a tank or canal, where they may be used for irrigating the crops when the main source has ceased to supply water; such wells often play an important role in the saving of crops.

Wells may not always tap powerful springs or large water-bearing strata and supplies may not be as abundant as may be needed, and may give out in times of great drought. Surveys of subterranean water sources which may furnish inexhaustible supplies as in the case of the very deep wells in California may probably reveal the existence of such sources in India also and are worthy of being undertaken. Deep wells can no longer be left out of consideration as unfit under Indian conditions, because mechanical power like steam, oil and electricity for operating deep well pumps are now largely available and depths deemed too great for animal power can be easily operated under these new conditions.

A somewhat peculiar source of irrigation which is partly subterranean and partly surface flow is to be seen in the sandy outwardly dry beds of some of the rivers of South India. In these apparently dry beds there is running water below the surface, which is reached by open cuts along the beds into which water continues to percolate and flow and to increase in volume, until after a short distance there is sufficiently good supply for irrigating adjoining fields by surface flow in the same way as water from tanks or river channels. The cuts have to be continuously kept in repair,

to be deepened and sides prevented from sliding in, by gangs of men usually the cultivators themselves or their paid men.

Quality of Irrigation Water

(*a*) *River-Water.*—Though the need for irrigation is for the sake of the water irrespective of other considerations the quality of the water used has also some influence, though perhaps negligible compared with the water as such. Some sources are esteemed for their quality and some are not. The quality arises from the fact that irrigation water carries with it in suspension or in solution (or both) a good deal of fine silt, organic debris and (or) dissolved salts, according to circumstances. The water of many rivers is thick and muddy, carrying a heavy load of finely divided soil and during floods many of them carry, in addition, much vegetable mould and debris from the forests through which they may flow. It has been estimated in the case of the river Ganges that the suspended matter carried to the sea yearly amounts to some 350 million tons and that the Brahmaputra likewise carries about the same quality! Many South Indian rivers probably carry more. Where river-water is used directly on the land, much of this silt is deposited on it and materially enriches the soil. Many gardens of areca, coconuts and fruit trees on the banks of some rivers obtain a yearly accretion of such fertilising silt when these rivers overflow their banks during floods. The well-known fertility of deltaic areas and of the Nile Valley is due to the fact that the soil is almost entirely made up of the sediment brought down by the rivers. Of course, the tracts from which the rivers flow suffer a yearly depletion of their fertile soil correspondingly. Other rivers may carry little or none at all of such silt and the water may be sparklingly clear even during the floods. In Mysore, the Kaveri and Kapila rivers form a striking contrast to each other, the former muddy and brown and heavily laden with silt while the latter is dark and clear. At the junction of the rivers the contrast is most marked. The difference arises of course from the nature of country and the rocks which they traverse. If it is through banks and beds of highly weathered soft masses of earth the water is heavy and muddy with silt, while if it is through hard granite rocks or earth which is calcareous, then the water is clear. The silt of the former may be so great in quantity that the level of fields may be raised, if desired, by impounding the water and allowing it to deposit the silt and repeating this over two or three seasons. Such impounding is also carried out for the sake of the fertility which it adds to the fields and gardens.

(*b*) *Tank Water.*—For a like reason the water of many tanks also contains a large quantity of fine silt or soil brought down by the rains from fields and waste land lying higher up. In Mysore, engineers allow for a rise of level in bed of 1′ for every 30 years, which is a measure of this kind of silt accumulation. Much of the silt in

tanks is deposited in the bed itself and does not reach the fields which may be irrigated therefrom; but in many cases the silt is so fine that it does not subside as a sediment for many days and is carried to the fields during irrigation. Sometimes such fine silt is composed of very fine highly ferruginous clay or even colloid iron hydroxides from lateritic soil and such silt is known to cause injury to the soil, on which the water is put on for irrigation. On the other hand, the water of some tanks is brilliantly clear and totally devoid of silt. This is generally the case in the black cotton soil tracts and is probably due to the lime present in the soil. On the whole it may be said that with very few exceptions the silt-laden waters are much esteemed for their fertilising value.

(*c*) *Sewage Water.*—Around towns and cities sewage water is used for irrigation and it is highly esteemed for its fertilising value, and market gardeners usually make use of every drop available for irrigation. Sewage is of different types depending upon whether it is merely the sullage and washings from the town or comprises the contents of water closets, and in the latter case whether it is used raw or after treatment in septic tanks as a clear fluid. In the raw state the sewage is heavily laden with suspended matter, while, after treatment it contains principally only dissolved salts. The former is therefore the more valuable of the two from a manurial point of view. In all cases, however, the material has considerable fertilising value and the cumulative effect of frequent and liberal irrigation will amount to a heavy dose of manure. (This subject is dealt with further in the Chapter on "Manures".)

(*d*) *Factory Effluents.*—Sometimes the water of streams, rivers and tanks may become unsuitable for irrigation on account of effluents from factories which may be let into them. Acids, alkalies, tarry matters, various different salts, etc., depending upon the products of the factory will pollute the water and the tolerance of vegetation against such water and methods of purification appropriate to each case will have to be adopted before letting the effluent to flow into the rivers, streams or tanks. Much caution is therefore necessary in utilising such water for irrigation, and this matter will assume much importance with the industrial expansion in the country.

(*e*) *Well-Water.*—The waters of wells, though free, almost entirely from suspended matter or silt like the turbid water of tanks and rivers, always contain salts in solution. These salts may be of many kinds, such as, sulphates, chlorides, carbonates and nitrates of sodium, potassium, calcium and magnesium; occasionally special springs may contain sulphur, iron and probably even some 'trace' elements, which are esteemed medicinally and are seldom present in ordinary irrigation wells. Waters may differ not only in the kind of salts they contain, but also in the total content in solution. Waters from wells which traverse strata of limestone or much disintegrated pegmatitic rocks are generally heavy with such salts; they are 'hard' waters and difficult to lather with ordinary soap and when used

in boilers leave a heavy deposit of scale, making them thoroughly unfit for that purpose. As potable water too many of the salt-laden waters are bitter and unpalatable, and should be deemed unsuitable. From the point of view of irrigation, however, they are mostly innocuous; on the other hand, certain wells are esteemed for the fertilising value of their water. Well-known cases are certain well-waters in Gujarat which have been found to be very beneficial to the tobacco crop on account, it is stated, of the potassium nitrate contained by them. Another interesting case of such a well is recorded from Bangalore, the water of which was found to contain 9·52 parts per million of nitrates and ammonia, equal to 1·7 per cent. of nitrogen per acre-inch of irrigation or 85 lb. of nitrogen equal to 54 tons of ordinary cattle manure per acre for a 50 acre-inch irrigation. (*Mys. Dept. Agric. An. Rep.*, 1902–03.)

The salt content as it affects the suitability of the water for irrigation relates both to the kind and the nature of the salt. If they should consist of the salts of sodium, such as carbonates, bicarbonates, chlorides and sulphates, then about 100 parts per 100,000 parts will make it unsuitable; if again 80 per cent. of the salts should be in the form of bicarbonates, even 80 to 100 parts total salts per 100,000 parts will make it harmful. The presence of calcium salts makes the water less unsuitable; thus, if calcium forms 25 per cent. of the total bases in the salts, even 170 parts of total salts per 100,000 parts will be tolerated. If nitrates are present in addition then even when the total salts go up to 270 parts per 100,000 the water will not be unsuitable, this result being due to increased vitality of the crop on account of the nitrates (see also Dulip Singh and D. R. Chawla in *Ind. Farming*, Aug. 1946). Generally, if the total solids exceed 60 per 100,000 then the case is considered one for being further looked into.

In a study of the salt content of the water of many wells, it was found that the quantity was surprisingly high, going up to even ·5 per cent. (in a well in Ajmer-Merwara and ·488 in a well in Delhi). Potable water should not contain more than 600 parts per million, which is the limit fixed by convention by sanitary engineers. Sea-water will contain about 34,000 parts per million and rain-water about 20 parts per million.

Methods of Applying Irrigation Water

Irrigation water is applied in nearly all cases on the surface of the field. In certain special cases it may be applied below the surface in trenches and in very exceptional cases may be given by an overhead system imitating a shower of rain.

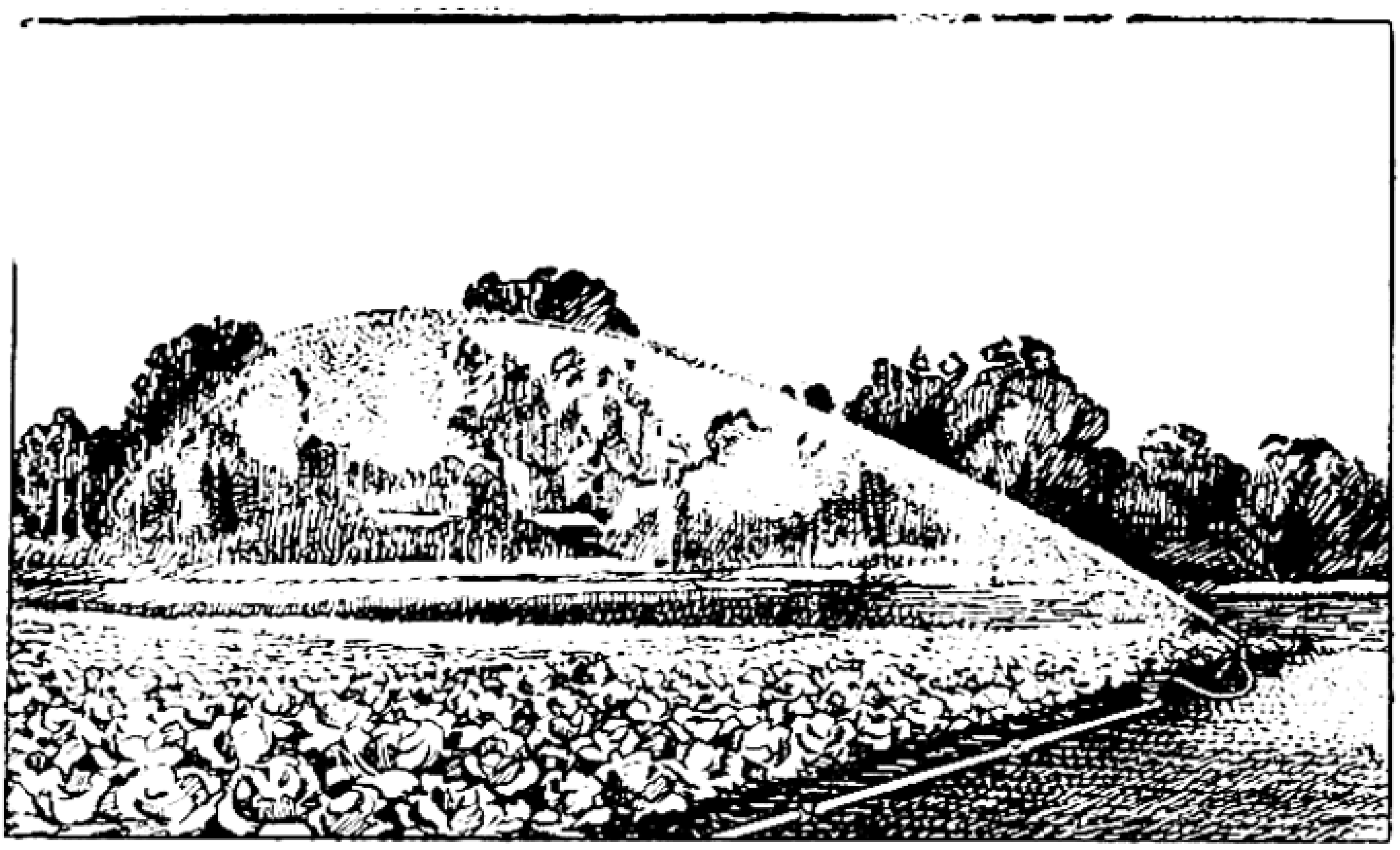
(*a*) *Surface Irrigation.*—Surface irrigation, which is the commonest system, is given in one of the methods, *viz.*, (1) bed irrigation, (2) furrow irrigation, and (3) basin irrigation.

(1) In the bed method, the field is laid out into rectangular beds and provided with small irrigation channels for the flow of

Irrigation of orchards, California (U.S.A.), water being allowed to flow in five furrows, instead of flooding the surface. *Photo by Author*

A large stone riveted percolation well supplementary or subsidiary to tank irrigation, showing also the *mbote* fixture at one end. The large storage capacity is noteworthy.

Photo by Author



Overhead or spray irrigation by outfits manufactured by Messrs. Sigmund Pumps (Great Britain), Ltd.

By Courtesy of the Company

Overhead or spray irrigation by outfits manufactured by Messrs. Sigmund Pumps (Great Britain), Ltd.

By Courtesy of the Company

water, the arrangement being such that two series run opposite each other alongside the channel. The arrangement is repeated series after series until the whole field is laid out in this manner. Water is let into each bed until the bed is soaked to the degree desired; it is then cut off and led into next bed, after finishing which the next one is taken up and so on until the field is completed. The beds are quite level (except where they have to be very large) and the crops (planted in lines or sown broadcast) stand in the water during irrigation with the water bathing the bottom of the stems. The water however readily soaks into the soil and not allowed to stand in the bed.

In the case of rice, the beds are made much larger; the surface is practically level with a very gentle slope to one side so that the water can flow very slowly; the field is then flooded and the water is allowed to stand in the field for many days at a stretch for a height of one or two, but up to even six inches, depending upon the stage of the growth of the crop. Water is not drawn off completely except towards the end, when the crop is almost ready for harvest. In this kind of special bed irrigation, the soil is completely submerged for several months. Such irrigation is peculiar to only rice (and the crop called 'baje' *Acorus calamis*).

2. In furrow irrigation the rows of the crop are divided by a furrow which runs between one row and another and water is let into these furrows, one after another until the soil is soaked to the desired extent. The base of the stems in this case is not touched by the water, in fact the rows stand in earthed-up ridges which divide one furrow from its neighbour. Even in furrow irrigation the field has generally to be divided into beds, small or large, within which run furrows alternating with ridges. The length of the furrows has to be moderate and seldom exceeds 15'; usually they are much shorter. This makes it easier for the water to flow properly and to irrigate the crop economically. Much ingenuity is displayed in the layout of beds with furrow irrigation, the object being mainly the economical use of water and this is a great consideration in lift irrigation where the raising of water becomes very costly.

3. In small-scale irrigation of fruit or flowering plants, water is often applied in basins, square or circular, round the plants, whether water be carried in pots by hand or applied as flowing water through small channels. The base of the plants or bushes should be earthed up so as to form a small mound around the stem and to protect it from actual contact with the water, as the latter condition may sometimes favour collar rot or other stem disease. The protection can be given in the shape of a collar by means of a short length of ordinary sheet tin or an earthenware pipe. In the great orchards in the irrigated sections of the U.S.A., water is let into large deep furrows in between the rows of the trees, two or three of which traverse this space and effectively saturate the orchard. Water is seldom obtainable in such large abundance in India for irrigation this way, but

occasionally groves of fruit trees can be seen irrigated by flooding the whole garden.

Surface Irrigation and Tilth of Soil.—Surface irrigation has the effect of spoiling the tilth of the soil by making the soil particles cohere, which is just the opposite of what tillage brings about. If the whole field has been irrigated in beds by flood irrigation, the whole surface is affected while, in the case of furrow irrigation, only the furrow bottoms are affected and the soil round and near the crop rows is intact. This effect of irrigation is remedied in practice by stirring or hoeing the surface by hand tools or bullock implements when the surface of the soil dries up sufficiently for the operation. The hoeing restores the tilth, which is essential for the aeration of the soil and the conservation of the soil moisture. Such hoeing is carried out in all cases after every irrigation until the rows close up and cover the ground when hoeing becomes impossible. Soils which are somewhat clayey may develop numerous cracks on the surface if the interval between two irrigations is prolonged and in such cases a timely hoeing becomes very necessary.

(*b*) *Sub-Surface or Trench Irrigation.*—This kind of damage to tilth is very harmful in the case of clayey soils and the black cotton soils, the particles of which cohere into a paste, the former dries very hard and both crack later, all of which injure the crop materially. In such soils, therefore, the method of "sub-irrigation" is sometimes adopted. Deep trenches about 3′ deep and 18″ to 2′ wide are dug lengthwise in the field, separating stretches of ridge which may vary in width according to the stiffness of the soil and the crops to be grown. A variation of the same method is to dig cross trenches in the same way, so that square ridges are formed surrounded by trenches on all sides, and the crop is grown on these ridges. The system is adopted in loamy soils also in the case of delicate crops like betel leaves, which are injured by water standing in contact with the base of their stems. Many garden crops like turmeric, yams, plantains and even sugarcane are grown under this method. The irrigation water runs only in trenches and does not flow on the surface and moisture reaches the roots laterally and from below and not from above as in the method of surface irrigation. In the hot weather when the need for water is great the water in the trenches may be help up and prevented from flowing out by means of low cross-bunds here and there in the trenches, avoiding surface irrigation even at this season.

(*c*) *Overhead Irrigation.*—A somewhat novel method is an extension or imitation of the method of watering lawns by means of sprinklers or 'roses'. In the U.S.A. there is a certain amount of vogue for the method, especially in the case of expensive garden crops. Water is carried under pressure in a system of overhead pipes or stand pipes on the ground which are provided with nozzles either fixed or rotating, at suitable points and from which the water can be forced through in the form of a spray distributed in a wide circle

over the crop below, wetting both crop and soil, in the manner of a shower of rain. Even though plants are not credited with the power of taking up moisture through their leaves and stems (some important exceptions are however coming to light), the spraying has a freshening effect due probably to the washing and cleaning of the leaves of dust and dirt, as may be seen in the case of ornamental foliage plants which are syringed with water occasionally. It is claimed that water in quantities sufficient for irrigation purposes which will moisten the soil to some depth can be forced through in this method. As a matter of fact, "raining" outfits both for stationary use and capable of being transported from place to place in the garden or field are already on the market, which, it is claimed, can shower water at rates equal to ¼" to ½" of rain per hour. It is, of course, of very limited application much in the same way as growing crops under glass or under a canopy of cheese cloth. Many improvements have, however, been made in the construction of the outfits, in order to make them suitable for various conditions and for greater convenience in practical handling and it is reported that the use of these outfits is rapidly increasing.

The advantages claimed for the method are: (1) There is no need to open channels either for the main supply or for distribution. This means that the entire field is available for crops and no space is taken up or cut up by channels. (2) There is no need to level the land, lay it, put into beds, terraces and so on, which means a great saving in cost; terracing may indeed be not possible where the soil is not sufficiently deep. (3) On sloping land it is possible to irrigate without fear of erosion. There is no waste of water in channels and distributaries, as the whole supply is made over the cropped area. In fact the method is tantamount to a shower of rain, but under controlled conditions.

On the other hand, the need to maintain a constant supply at high pressure for which sufficient power is necessary, and need to have a supply of clean, clear, grit and mud-free water, so that the sprinkler nozzles do not become clogged or worn, are great difficulties, because in practice it is on only in exceptional situations that such supplies may be available. Above all is the great cost in the outfits, which make it prohibitive except in the case of very profitable crops and under favourable conditions.

QUANTITY OF IRRIGATION WATER AND FREQUENCY OF IRRIGATION

Many accurate experiments have been conducted in order to determine the quantity of water required by crops for the production of their normal yields and this quantity has been expressed in a ratio of the quantity of water per unit of dry matter produced. This quantity of water represents the quantity which has been used up by the crop during growth and does not take into account the various losses which are inevitable in actual field husbandry, and is, therefore, a figure which is very much less than what one

should provide for in irrigation. These losses are due to surface evaporation, percolation, transmission losses which include both the above as they may take place during the transit of the water to the field, in addition to losses due to leakage and other imperfections of the conduit in practice. It is obvious, therefore, that only field experiments under the conditions which may be prevailing in particular irrigated tracts can give figures which may be relied upon in practice for providing the required quantities of water. Such experiments also have been conducted for many crops and the figures are given elsewhere (see under Duty of Water). The pot experiments conducted under accurate and controlled conditions bring out however one important fact, *viz.,* with how little water most crops can be grown to perfection, if only *all* the water could be utilised solely by the crop without even a drop of it being lost due to any or all the causes mentioned above.

The figures showing the quantity of water required for producing one pound dry matter of the matured crop may now be given. It may be stated that there is very material variation in the figures arrived at by different workers, in addition to the fact which is only to be expected that figures vary for the different crops and for the same crops under different climatic conditions. German figures vary for example from 233 lb. to 774 lb. of water per pound of dry matter, American figures from 271 lb. to 576 lb. in humid climates and from 589 lb. to 1,118 lb. under arid conditions. The figures in India which are available are few; for *juar* it has been found to be from 400 lb. to 500 lb. (Bijapur) and for *bajra* from 300 lb. to 550 lb. (Panjab) per lb. of dry matter. If, on the basis of the above figures, about 450 lb. should be taken as the average requirement, then a 2,000 lb. dry matter crop of *juar,* for instance (which is a good yield), will require only 450 $\times$ 2,000 lb. of water or about 400 tons; this will be supplied by as little as 4″ of rainfall, if *all* the rain should be utilised by the crop. Highly theoretical as the figure is, it shows what may in reason be expected if all possible measures are taken to conserve moisture.

According to another estimate which is furnished by Vagelar (*An Introduction to Tropical Soils*), the rainfall required under these conditions (*i.e.,* if every drop of the rain is used by the crop) for obtaining the best yields of some tropical crops is as below: cereals—4·8″ to 6″; maize and millets—8″ to 10″; oilseeds—4·8″ to 6″; cotton—8″ to 10″; coffee—10″ to 12″. Under field conditions, that is to say, making allowance for all the different kinds of losses of the rainfall, he would multiply these quantities by five, as according to him only some 20% of the rainfall is made use of by the crop.

Frequency of Irrigation and Factors Influencing it.—Data regarding the quantity of water required at each irrigation and the intervals that can be safely allowed between two successive irrigations assume great importance in India for determining the area which

any particular irrigation source can irrigate in respect of the different crops.

It is necessary that the moisture in the soil available to the plant should be such as to ensure normal continuous growth; the break between two irrigations should not be so long as to reduce the moisture below this level. The length of this interval will depend upon the soil and upon the crop primarily and upon the season, whether rainy or rainless or the hot weather itself. As soils with a high clay content are more retentive than the loams and sandy soils, a longer interval may be allowed on the former than on the latter. Likewise as crops differ in their root system, in respect of their ability to make use of moisture at lower depths which have generally sufficient moisture even when the soil near the surface or the upper layers are not moist, a longer interval can be allowed in the case of deep-rooted crops. Seasons affect the interval also for obvious reasons and longer intervals are possible in the rainy season than in the hot rainless months. The frequency will also depend upon the stage in the growth of the crop; during certain stages, particularly the later stages, crops require much larger quantities than in the earlier stages; there is, in fact, a maximum or 'grand phase' in regard to irrigation. Sugarcane for example will require much heavier irrigation from about the sixth or seventh month onwards, *i.e.*, for about four months previous to maturity. Similarly the grain crops require their maximum irrigation from the time that the earheads are forming and about to appear.

The situation of the land, whether on a slope or on the level, will also influence the frequency of irrigation and, especially so, according as the soils are porous or retentive. For example, in the sugarcane-growing tract around the Mandya Sugar Factory in Mysore, the country is very undulating and the fields lie on a slope in large terraces. The soil contains a large admixture of coarse gravel which makes it very open and the percolation is very great. The crop cannot stand any long interval and irrigations have to be more frequent. On the other hand, in the sugarcane tract under the Nira canals (Bombay Presidency) where the fields are on the level and the soil of the retentive black cotton soil type a much longer interval can be allowed, and the frequency may be reduced. In between, will come the sugarcane tracts of Upper India, which are on a dead level and the soils are of an intermediate type being light or heavy loams. The interval should nowhere be so long as to cause wilting to set in, even though the crop may be known to revive with great rapidity after irrigation is restored once again. This length can be decided only by practical test under each condition of soil, climate and situation. The moisture content of the soil for normal growth in the particular soil will however afford some guidance and the irrigation should be at intervals which will maintain this degree of moisture, as far as may be possible.

The frequency can be to some extent reduced by keeping the surface well stirred or hoed after each irrigation. This may not be possible when the crop has grown up and covered the space between the rows, but before this stage is reached the hoeing should be frequent and thorough. The objects aimed at are firstly, to reduce the loss of moisture from below and secondly, to induce deep rooting. The deep rooting is likely to be encouraged by the drying of the top soil brought about by the hoeing and the consequent forcing of the roots to seek moisture lower down. If irrigation is frequent and no hoeing is done, the roots will crowd near the surface and the crop will begin to suffer and wilt, if the irrigation is not continued in the same manner without abatement. In the case of the ordinary crops the hoeings will always be possible in the early stage and deep rooting can be stimulated; when later the rows close up and hoeing is not possible, there will not be the same need, as the loss of moisture by evaporation will be kept down by the shading effect of the crop.

Conservation of Irrigation Water

Irrigation water is subject to losses from many causes which have to be prevented as far as possible, so as to conserve it for the use of the crop. Some of these causes have already been referred to, *viz.*, surface flow, percolation and evaporation. Well-levelled fields suitably bunded up will largely reduce loss by surface flow, while the frequent manuring with organic manures and the addition of tank silt or clay will reduce percolation losses. The reduction of evaporation by frequent hoeings which produce a soil mulch and which destroy weeds at the same time and thereby keep down the loss of soil moisture has already been referred to.

A somewhat serious loss arises during the transmission of the water. Both the main canals and the distributaries run merely in cuts in the ground and therefore on an earthern bottom and between earthern banks, both of which allow of much loss by percolation, not to speak of cracks, holes and gaps. Such loss in the Panjab canals (Lower Chenab) has been reported to amount to quite 33%. In some irrigation systems, the canals are cement-lined and beds and sides are practically water-tight. Short of bringing the water in closed pipes this avoids percolation losses almost completely. A cheaper method recommended consists in puddling the bottom and as much of the sides as possible with fine clay containing sodium carbonate, which also produces a fairly water-tight surface and reduces percolation. The saving in this case, after such treatment in some Panjab canals amounted to 2·3 cusecs of water. These are however matters for the irrigation authorities. The author has personal knowledge of some large land-holders in Mysore who have laid out a perfect system of good masonry flumes or conduits for leading water from their tanks to the fields, and have thereby husbanded their precious tank water. The matter assumes great

importance in well cultivation and it will be the height of folly to waste water in transmission. The author has also come across cases where water raised by water-lifts using two pairs of bullocks, being led for nearly a furlong through a small earthen channel to the field; the amount of valuable water wasted in the transmission can be imagined and when the humble means of the cultivator concerned are also considered, it must be regarded a sad sight. Glazed earthenware pipes or semi-cylindrical half-pipes, masonry channels or flumes of corrugated iron sheets or other similar arrangement is very necessary in practically every case of well irrigation. The importance of such conduits is not unknown and cases can be met with here and there, especially in sandy tracts, of good cement-lined or masonry conduits being used. If pipes can be used even the loss by evaporation in transit can be avoided and this is also worthy of consideration, where the value of the produce raised will justify it. Something approaching perfection in these matters can be seen in the deep well irrigation arrangements in the orchards of California.

Measurement of Irrigation Water

Irrigation water is measured in one or other of the following units, *viz.,* (1) the cusec, which is short for cubic foot per second, (2) the acre inch (or sometimes the larger unit, the acre foot), (3) on a small scale, especially in lift irrigation, in actual gallons or gallons per hour.

The cusec is the quantity of water flowing at the rate of one cubic foot per second. The actual quantity will of course depend upon the number of hours (*i.e.,* the length of time) during which the supply was made at this rate, *i.e.,* during the time the water flowed at this rate. As a cubic foot of water weighs $62 \cdot 5$ lb. the quantity in weight can be easily calculated; a cusec flowing for one hour will thus be equal to $62 \cdot 5 \times 3{,}600$ or approximately 100 tons.

The 'acre inch' is the quantity of water which will cover one acre of surface 1″ deep. Expressed in quantity by weight, this will amount approximately 100 tons also; so that 1 cubic flowing for 1 hour will give 1 acre inch. Rainfall too is measured in the depth in inches over any area and an inch of rainfall also means an acre inch. A 10″ rainfall will be 10 acre inches, and acre foot will be 12″ of rainfall and so on.

In the case of lift irrigation whether by ordinary mhores or by pumps, the quantity lifted is expressed in gallons per hour. The capacity in gallons of the mhote bucket and the number of buckets brought up per hour will give the quantity lifted per hour in gallons. The capacity of pumps is usually known and the quantity discharged during any period of time can be calculated. A gallon of water weighs 10 lb. and the quantities in gallons, of cusecs and acre inches can be easily calculated. The three units can therefore be expressed in terms of each other.

In the case of irrigation tanks, the quantity of water that can be stored, *i.e.,* the capacity of the tanks, is expressed in terms of 'units', a 'unit' in this case being 6 acre feet or 72 acre inches. It is assumed that this quantity of water will be required under average conditions for 1 acre of rice, so that a tank of capacity of 50 or 100 units is one which will furnish enough water for 50 or 100 acres of rice respectively. If the *average* depth of water in the water-spread of a tank should be 6′ (as is the case in many tanks in Mysore) then the extent of rice land under the tank in acres (or the capacity of the tank) will be the same as the area of the water-spread.

Duty of Water

Another expression used in this connection is the 'duty' of water. This is used to denote the number of acres of any particular crop which can be cultivated with a continuous flow of irrigation water of 1 'cusec' throughout the growing season of the crop. The 'duty' will vary therefore with the different crops, with the nature of the soils, with the kind of crop season, *i.e.,* whether in the rains or in the hot weather with the method of cultivation (*i.e.,* in puddle or partly dry and partly in puddle) with the method of irrigation and the care with which the water is used. It will also vary with the yield of the crop. On good soils and with heavy manuring more water will be required and the 'duty' will be less. The reasons are obvious. In the case of garden crops and under lift irrigation the duty will be higher than in the case of rice or under tank or channel irrigation. On undulating country and with terraced fields the duty will be much less than where the country is flat and the fields are level.

For these reasons, the duty of water for the different crops varies in practice within very wide limits; for example, for rice the duty has been found to be 25, 28, 30, 35, 40, 45, 55 and 66 acres, with an average of 38·6 acres per cusec (figures collected by Prof. King). The duty for sugarcane varies form 41·6 acres to a maximum of 60 acres. The Bombay D.P.W. Handbook fixes a duty of 40 to 45 acres for sugarcane, 40 to 45 acres for rice, and 80 to 85 acres for irrigated cotton, giving at the same time the number of waterings prescribed for the different crops as under: Sugarcane—30 to 35; bajra and other monsoon crops—2 to 3; *juar* and other rabi crops—3 to 4; and crops of 8 months' duration—10 to 13.

If the number of acre inches of water consumed by any particular crop throughout its growth (from sowing to harvesting) is found out by actual experiment then the duty of water for that crop can be calculated. Thus, for irrigated wheat, the quantity of water actually consumed (in experiments in Cawnpore) during its cultivation period of 4 months was 8 acre inches (exclusive of rainfall). The duty will be given by dividing the quantity in lb. which 1 cusec will supply running continuously for 4 months, by the above 8 acre inches calculated in lb. For the above example it

will be $\dfrac{4\times30\times24\times60\times60\times62\cdot5}{8\times100\times2240}$ or about 360 acres. For hot weather ragi, during a period of 3 months, the water consumed was 13 acre inches. The duty at this rate will be $\dfrac{3\times30\times24\times60\times60\times62\cdot5}{13\times100\times2240}$ or about 166 acres.

The water requirements of some of the irrigated crops were found by Prof. R. C. Wood to be as follows :—

Crop		Period in months	Quantity (exclusive of rainfall) in acre inches
Rice	..	5	37
Ragi (rainy season)	..	3	9
Do. (hot weather)	..	3	13
Juar	..	4	10
Sugarcane	..	12	50
Maize	..	4	15
Wheat	..	4	8

The duty of water under the above conditions for the crops listed can be calculated from the data given.

Lift Irrigation—A. Wells

Next in importance to supplies from surface water of rivers and tanks, which are made use of mostly by gravity flow, comes the supply from underground, which has to be raised to the surface for application to the soil. Subterranean supplies are tapped and made use of by digging wells, and well irrigation is really synonymous with lift irrigation, although to a certain extent water may here and there be lifted from tanks, rivers and canals for irrigation. Well irrigation assumes great importance where facilities for gravitational flow like rivers and tanks do not exist and where abundant supplies of underground water may be available within easy reach. Even in areas of tank and channel irrigation, well irrigation may largely be resorted to side by side, in order to make cultivation possible in seasons when the tank or channel supply is cut off and for emergencies for saving the crop.

Types of Wells

The raising of water from wells in India is largely by means of animal power and this circumstance very materially influences the character of the wells to be dug. In the first place it limits the depth of the well; the level of the water to be raised cannot be deeper than about 30′ and in practice the water has to be within 20′ or 25′ from the surface. In order therefore to have sufficient

capacity to be able to irrigate say about 3 acres (which is the capacity of good irrigation wells) the supply in the well has to be ample, being derived from good springs fully saturated or porous sandy rocky beds and sides, which will replenish the supply as quickly as it may be used up, or the well must be given sufficient length and breadth so as to have a large stroage capacity.

This and other features of irrigation wells are of very great practical importance and may now be briefly dealt with, taking as examples irrigation wells in Mysore. Although the State itself is not particularly suited for well irrigation, there is a considerable area which is under well irrigation and many interesting types of wells may be met with, the peculiar features of which may find application in other parts of the country as well. The state lies on a plateau with a general elevation of about 2,000′ above sea-level and the surface is very undulating and much of it is rocky and hilly with extensive outcrops of rocky surface and prominent hills of bare rocks. Underground water sufficient for storage can be met with only at great depths; in most places hard sheet rock is met with at very low depths, when work will either have to be given up or blasting and cutting through the rock attempted, in the hope that a water-bearing layer or spring will be struck lower down.

(*a*) *Percolation Wells.*—Many large wells can be found in arecanut and other gardens situated below irrigation tanks and these contain only percolation water, the level of which rises and falls with that of the water in the tank. Water however remains in the wells for many months after the tanks dry and is available for irrigation. These wells are more in the nature of large stroage reservoirs for holding the percolation from the tanks, are generally very shallow and are underlaid by hard rock. They may have all the four sides riveted or only one face where the mhote may be fixed.

(*b*) *Wells through Soft Earth.*—Very large wells are sunk through compact unweathered whitish clay, until a good spring flow from scattered springs from the bottom or the sides are met with. These wells are riveted with stones and are of considerable size, being even 20′ to 30′ in diameter and about 30′ to 40′ deep. Their sides are very liable to cave in and special arrangements will have to be made by means of strong and substantial curbs to prevent such caving in. In spite of the best efforts, many wells cave in and will have to be abandoned with disastrous loss. Large concrete curbs in sections of 2′ to 3′ in height are coming into use for building such wells without the risk of the sides caving in. The chief difficulty is often the unwatering of the wells quickly enough before the sides in contact with the water slip down. Power-driven pumps of good size can be of much service for this purpose and will make it possible to reach sufficient depth without the sides coming down. A very large number of both irrigation and domestic supply wells are of this type.

(*c*) *Wells through Rock.*—In other wells soft rock is met with, in which there is no such danger of the side slipping at all and good depths can be attained in safety. It is in such wells that good water-bearing veins of pegmatite, limestone, or other crumbling decayed rock can be met with and a good supply obtained. The sides may or may not require riveting, although a few feet of depth near the top which pass through soft soil will need rivetment.

(*d*) *Wells through Water-bearing Sand.*—Other wells with equally good supplies of water are found in the sandy valleys of some of the rivers and streams in the eastern taluks; a sandy layer is reached at a short depth and the well will have to be dug through this water-laden sand. A wooden frame, either circular like a cart wheel or rectangular like a large door frame and made of heavy timber, is now sunk at the bottom and built upon to a short depth, the inside being cleared and deepened; the framework with the structure on it sinks slowly, until generally bed-rock is reached or stopped short where desired. The structure is then built upon course by course till the riveting is complete to the top. The structure may be of stone or brick in mortar, through which water forces itself and fills the well. Cement curbs with 'weep holes' are being recommended instead and are probably more convenient and permanent.

(*e*) *Wells in Beds of Laterite.*—Other wells are small square or rectangular excavations made in somewhat hard lateritic material, whose sides are firm enough to stand without the need for riveting; the inflow of water is generally small and the wells are as a matter of fact only for use with a picota lift worked by one man or more depending upon the depth of the well and serve the needs of only a patch of potato or other crop on about 10 or 20 cents in extent.

(*f*) *Temporary Wells in Sandy Beds.*—At the lowest end of the series is the temporary well sunk in sandy or soft soil, the sides of which are protected by a well curb made of wicker work. These may last two or three seasons, and are sometimes large enough even for a bullock mhote to be fixed.

(*g*) *Deep Wells for Drinking Water.*—In many parts of the country wells are almost unthinkable as the depth will have to be too great; some 70′ or 80′ will have to be dug before water can be struck; though irrigation wells are obviously out of the question the all-important need for drinking water requires that drinking-water wells should be sunk even at this depth and in many villages raising water from these wells for household use is very arduous.

All the above-mentioned wells belong to the type of 'open' wells.

(*h*) *Bore-Wells.*—The introduction of well-boring equipment (both manual and power-driven) has made it possible for such villages and tracts to obtain a more satisfactory supply but their application for irrigation purposes is limited, as a large enough underground flow is seldom met with. In the case of the large existing irrigation wells which have a hard rocky bottom, a deeper borehole through the rock sometimes brings in supplies, for which the well

provides sufficient storage capacity and the water-level comes within 20′ or 25′ suitable for ordinary mhotes. On the plateau the underground rock formations are not favourable according to geologists, for any large and inexhaustible supplies, except in rare instances of a water-bearing stratum being broken by a 'fault' and the water held up under pressure. In the plains however conditions are different and favourable and in recent years modern well-sinking machines have been employed with great benefit and many deep wells with plentiful supplies have been sunk or old disused wells put in action again.

(*i*) *Tube Wells.*—The tube wells are very much similar to the bore-wells, except that they are sunk in sandy or soft highly permeable water-holding strata, which do not require boring by means of special boring or rock-drilling machines. They are, on the other hand, tubes or pipes which are driven or forced down into the ground by mere pressure and are sometimes referred to as "driven wells". The tube itself serves as the well, being strong enough to withstand the pressure from the sides, while 'well point' with plenty of perforations and fixed to the lower end of the tube permits the water entering into the tube. The tube itself may form part of the pump or the latter may be a separate one, fitted inside the tube. The pump barrel, or the casing in the case of centrifugal pumps, is below the level of the water and submerged, while in the case of many modern types, the pumps are air-lift pumps worked by means of compressed air.

Tube wells form a characteristic feature in the U.P. and are fitted with electrically-driven pumps, irrigating several hundred acres each.

(*j*) *Filter-point Wells.*—In many places where the water-table is within about 15′, pumping sets, using 'filter-point' tubes to suck the water through, which are driven into the ground down into the water-laden sand or other layer, are installed. The tubes have their bottom end shaped like a pencil-point and are capable of being driven into the ground comparatively easily through the soil. The ends are also perforated and the water enters through these perforations into the pipe (or tube) and is sucked up by the pump. Above ground the tube is connected with the pump which operated by an electric motor or oil engine, lifts and delivers the water just as from an ordinary well. These installations are becoming common in the deltas of the Kaveri and Godavari rivers in South India.

(*k*) *Artesian Wells.*—Supplies of underground water from 'Artesian wells' do not require lifting or pumping up, because the water is under great pressure and rises to the surface of the ground and in many cases up to a great height and keeps continuously flowing. These 'Artesian' wells can be found only where the peculiar geological formation exists in which a water-holding stratum is held between two impermeable strata, and where such formation has taken the formation of a basin or trough-like bend with the per-

meable stratum outcropping at both ends. A borehole put down at the bottom of such a basin will tap water under such great pressure that it may gush out like a fountain, the height and force diminishing as the boreholes are put down higher up the slope on either side of the bottom. Boreholes are reported to have reached even a depth of 5,000'. Famous 'Artesian' wells in the world are known to have sent up water to a height of 170'. Most however give only a continuous flow above ground and without the need for pumping. 'Artesian' wells are to be found in South India in and around Pondichery in the Madras Province where many such wells have been put down for irrigation purposes, the depth of the bores being however only a few hundred feet.

Selection of Sites for Wells

Despite limitations and difficulties, irrigation wells have to be sunk for such relief as they may afford on account of the great need. The selection of a suitable site where water may be expected to be found is a matter of much importance. Very often it is a 'hit or miss' venture, but risks may be minimised by attention to some well-known and commonly believed ideas. The existence of wells already in the particular area is a useful indication as regards the possibility of striking water and of the depth to which it may have to be sunk. In new areas, guidance is afforded by various factors which are popularly believed in; low lying places, bottoms of valleys or the lower slopes hold out the best chance and deserve first priority, but against this has to be set off the expense of a higher lift and the construction of a high embankment, for carrying the water to a high level so that the well may command a sufficient area. In plains and level country or high lying situations, the presence of tree vegetation is taken as an indication of underground water. Groups of well-grown trees, clustering together in otherwise bare country may indicate a suitable site; date trees, *Eugenia jambolana, Ziziphus jujube, Prosopis sperigera, Ficus glomerata* are among the indicators. Likewise ant-hills, the presence of frogs underneath the soil or inside of rock are also mentioned as indicators. In his *Brihat Samhita,* Varahamihira devotes 125 *slokas* to this subject, which sum up much valuable experience and are worth critical study.

Water Divining.—Some value in this respect is claimed for what is termed 'water divining'; certain people are said to be affected in a particular manner when they happen to walk on ground which may have a good underground supply of water. The more common way of utilising this gift is for the man to hold a forked twig or stick loosely in his hands, one limb of the fork in either hand and with the stem pointing upwards, and to walk along the ground to be explored; where there is a good underground flow or supply, the fork tips round and dips sharply with the stem end pointing downwards. Some claim that they can map a whole tract for subterranean supplies of water by this method!

Water Finder.—Mechanical indicators (one of which is the Mansfield Water Finder) rely on the deflection of a magnetic needle in the apparatus, said to be produced by the action of flowing water deep underground. In both these cases the depth at which water may be found where indicated (if it is a correct indication of water at all) will not be known nor is the mechanical indicator free from admittedly interfering factors. Nevertheless, the services of both the human and the mechanical water finders have sometimes been resorted to, and with success, it is claimed. One with a good knowledge of the country and of its geological peculiarities will be a reliable guide. In practice a small trial well (or a borehole if the equipment can be got) will afford the most useful information regarding the presence of water and the depth at which it may be struck, on which a decision regarding the site may be taken.

Improvement of Wells

Most wells in Mysore (and those similarly situated) are subject to the risk of going dry or too low to be of use in years of severe drought. If there is a succession of bad seasons, even very good wells, with perhaps three or four mhotes fixed to them, may go dry. In the drought of the years 1922 to 1924 in Mysore the author saw a well to which six mhotes were fixed and which would allow of four mhotes to work simultaneously had gone dry. The question of increasing the inflow of water into wells is often raised both in normal seasons and particularly in such abnormal seasons.

The improvement is generally attempted in one of the following ways, *viz.*, (1) by deepening the wells, (2) by driving adits or boreholes laterally into the sides near the bottom, (3) by shattering the rocky side or bottom by a charge of explosive. In the large majority of the irrigation wells whose bottom and sides are not of rock, hard or soft, it will be impossible to deepen them without danger; the only way in which some extra depth can be attained is by digging a very small well right in the centre of the bottom of the large well and rivet it strongly. This is sometimes done and generally a better flow is secured; but even this method is not without risk to the original well.

In the case of the wells sunk through sandy water-laden layers and which are riveted with stone, brick or cement curbs, it may be possible to excavate the bottom carefully, without detriment to the curbing on the sides, which slowly sinks as the well becomes deeper and the top portion may again be built up. It was discovered with some surprise during a campaign of well-deepening by the Mysore Agricultural Department that most of such wells had already been improved in this manner during former droughts more than once and the wooden frame or base below the curb was resting on solid rock, the sandy layer having been fully availed of.

In these cases and in case of wells with rocky or sufficiently hard sides and bottom, the deepening of the well can be attempted only

Artesian Spring flow, utilised for irrigation (outlet pipe bent suitably for the purpose) Logan, Utah, U.S.A.

Photo by Author

A "picotah" waterlift, with three men walking to and fro on the lever beam, to help the man at the bucket actually lifting the water.

Photo by Author

"Picotah" waterlifts of the ordinary type, being used on a very low lift, for baling tank water from below sluice level up into the sluice. Picture shows men at work at a number of emergency lifts fitted up for this purpose; this work is usually done co-operatively by all the cultivators of land commanded by the particular sluice.

Photo by Author

by putting a borehole down the bottom or by blasting the rock and deepening. There is a large element of chance in any improvement of the supply by the method, but that is about the only course open.

Where water is derived from porous rock, veins or cracks in the rock, then horizontal holes or 'adits' are bored through the sides for short distances and no deepening is attempted. A larger flow area is thereby tapped and, with luck, a good spring flow, as the result of which the supply is greatly increased. Rather a drastic method is to help the flow by creating more cracks and fissures in the otherwise compact homogeneous rock at the sides and bottom by exploding a charge of explosive and shattering the rock. It is stated that sometimes the method may have results contrary to what is expected and that far from improving the supply, even the original supply may be reduced. On the whole, the safest method of improvement would appear to be the putting down of a borehole by means of well-boring machinery down the bottom of such wells.

B. Water Lifting Methods and Appliances

There is a large variety of methods in India by which water is raised from a low level to a higher level. The simplest is that of raising it without the employment of any mechanical appliance at all but by merely lifting it by hand in potfuls and emptying it at a higher level. From a simple one-stage lift of some 2′ or 3′, this can be applied to much higher lifts by a series arranged like a flight of steps, the pot being handed up from the lower to the higher, moving up in a kind of human elevator. This primitive method is replaced by many kinds of appliances by which larger quantities can be raised quickly and with less labour.

These are: (1) The "swing basket" method, in which a conical basket is worked by two persons whereby a basketful of water is scooped up and hoisted in a swing on to a higher level and emptied and which can be used for lifts up to about 5′. (2) The "swinging wooden scoop", in which a large wooden scoop or shovel, with a long handle is slung from a tripod over the water to be raised, with which one man scoops up water from below and empties it on a higher ground. This device also serves only a lift of 2′ or 3′. (3) The "water wheel": this is a little arrangement of paddles fitted to an axle like the spokes of a wheel inside a box, the paddles being turned by pressing down with the feet, when each one carries with the water from below and empties it into a channel slightly above. Very low lifts of about 1′ or 18″ are served by this wheel. All the above lifts are very small-scale appliances, which can be fitted anywhere easily, can be worked by one or two men and are suited to lifts of about 5′. They are used moreover for lifting only surface water from a lower to a slightly higher level and often only as emergency lifts. (4) The next kind of appliances are those intended for raising water from wells and from above-ground sources and are suited for higher lifts. They comprise

(a) the 'picota' lift, (*b*) the 'mhote' or 'kapiles' of different types, (*c*) the 'Persian wheel' and its variants. These really are the appliances for normal lift irrigation. The picota lift makes use of human labour while the mhotes and the Persian wheel use bullock or other animal power.

(*a*) *The Picota Lift.*—This familiar appliance consists of a long transverse pole or beam mounted on an upright pillar or post fixed at the side of the well, in such a way that the beam moves see-saw fashion on the fulcrum provided by the post. The forward end of the beam carries a bucket slung from a rope and the rear end carries and is weighted by a large stone tied to it firmly, which partially counterbalances the water bucket and helps in easing the labour required for lifting the bucket from the well. The lift is generally worked by one man but help is given in different ways in easing the strain. For example, long ropes are tied to both the forward and the rear ends of the cross-beam which is pulled by a helper now one and now another as the bucket is raised or lowered; another method is for 2 or 3 men to walk along the lever beam, now on one side and now on another, to help with their own weight the raising and lowering of the bucket—a proceeding often attended with considerable risk. The lift is suited to both low and moderate lifts of even about 15′, the bucket may be small or large holding from 2 to 6 gallons. The quantity lifted will depend of course upon the size of the bucket, the depth of the well and the amount of help provided. It has been found however to be the most efficient in respect of work performed in proportion to the power applied. About 2,000 gallons can often be lifted per hour on a lift of 20′ with 3 men working the lift.

(*b*) The *Mhote* is the most important water lift for irrigation purposes; it is worked by bullock power and the quantity raised is large enough for irrigation. It contains more working parts than the picota, although it is very simple. Essentially it is a pulley hoist, the pulley wheel is erected over the well and the hoisting rope carrying the bucket at one end is pulled over the pulley raising the full bucket to the top of the well by a pair of bullocks. The mhote bucket is the cleverest piece of work and very elegant in its simple efficiency. It consists of a large leathern or metal pot-shaped bag with a wide mouth and its bottom portion is formed by a large leathern (or canvas) hose (somewhat like the trunk of an elephant). It is thus a sort of pipe, the top half pot-shaped and the bottom half a long hose and open at both ends, but the arrangement of the pulling ropes is such that when full and ready for raising from the well the bucket becomes U-shaped. The main pulley rope is tied to the mouth of the bucket and a smaller or tail rope is tied to the end of the hose and is passed over a small roller lower down and connected with the bullock end of the main pulley rope, both moving together as the bucket is raised or lowered. The full bucket which

is U-shaped when full is pulled up in this shape to the top of the well, where the tail rope is pulled taut by the driver when the hose straightens out and empties the bucket completely; the operation is automatic but for complete emptying the driver may give an additional tug, so as to straighten it fully. The power is furnished by a pair of bullocks which pull the rope, walking forward, the full length of the rope and raising the bucket in the process; they then walk the distance backward and lower the bucket into the well. The walk is down a ramp with a steep or gentle slope, which may vary from 1 in 3 to 1 in 5, so that it is really the weight of the bullocks (and the driver, who sits on the rope and adds his weight to the power) which constitutes the power. In one type, two ramps are provided, one a steep one for walking down and the other alongside but less steep. In this case the walking backward by the bullocks is avoided, they are unyoked at the bottom of the ramp, turn and walk up in a natural manner over the latter ramp; the driver meanwhile walks up the top of the ramp with the pulley rope in his hands and hitches the bullocks for the next journey down the steep ramp. Where the wells are very deep, then the downward ramp is very steep and 2 or 3 pairs of bullocks are used, one pair actually pulling and raising the bucket while the other two walk one behind the other leisurely up the less steep ramp. The arrangement has in fact to be watched when it is actually at work, for appreciating it properly as a description cannot give a sufficiently clear idea of the working. The mhote can serve depths up to about 30′ but lesser depths are more usual. The buckets will hold up to 40 or 50 gallons and the quantity raised will depend upon the height of the lift, the quality of the bullocks, the size of the bucket and also very often on its sound condition, as leakage due to old and torn buckets is very material. On the average about 3,500 gallons per hour may be taken as the capacity. The mhote is considered very efficient and second only to the picota. Much leakage of power may however occur and is common, through friction, lack of rigidity and general poverty of the materials used.

In many parts of Upper India the mhote contains no such automatic device for emptying but consists only of the bag or bucket; the animals pull the rope and raise the bucket from the well in the usual way, but the emptying is effected by a man standing near the mouth of the well who takes hold of the bucket and tilts it empty. Some of these wells are moreover astonishingly deep for open wells, going down some 200′ or 300′ (as in the State of Bikaner), the ropes are of a like length and the animals walk the same distance pulling the rope!

Improvements in Mhotes.—The mhote has been attempted to be improved in several respects but mainly in order to adapt it to the walking of the bullocks on the level instead of up and down over a ramp. More than one type of these models can be seen here and there; in all of them the bullocks are made to walk on a level

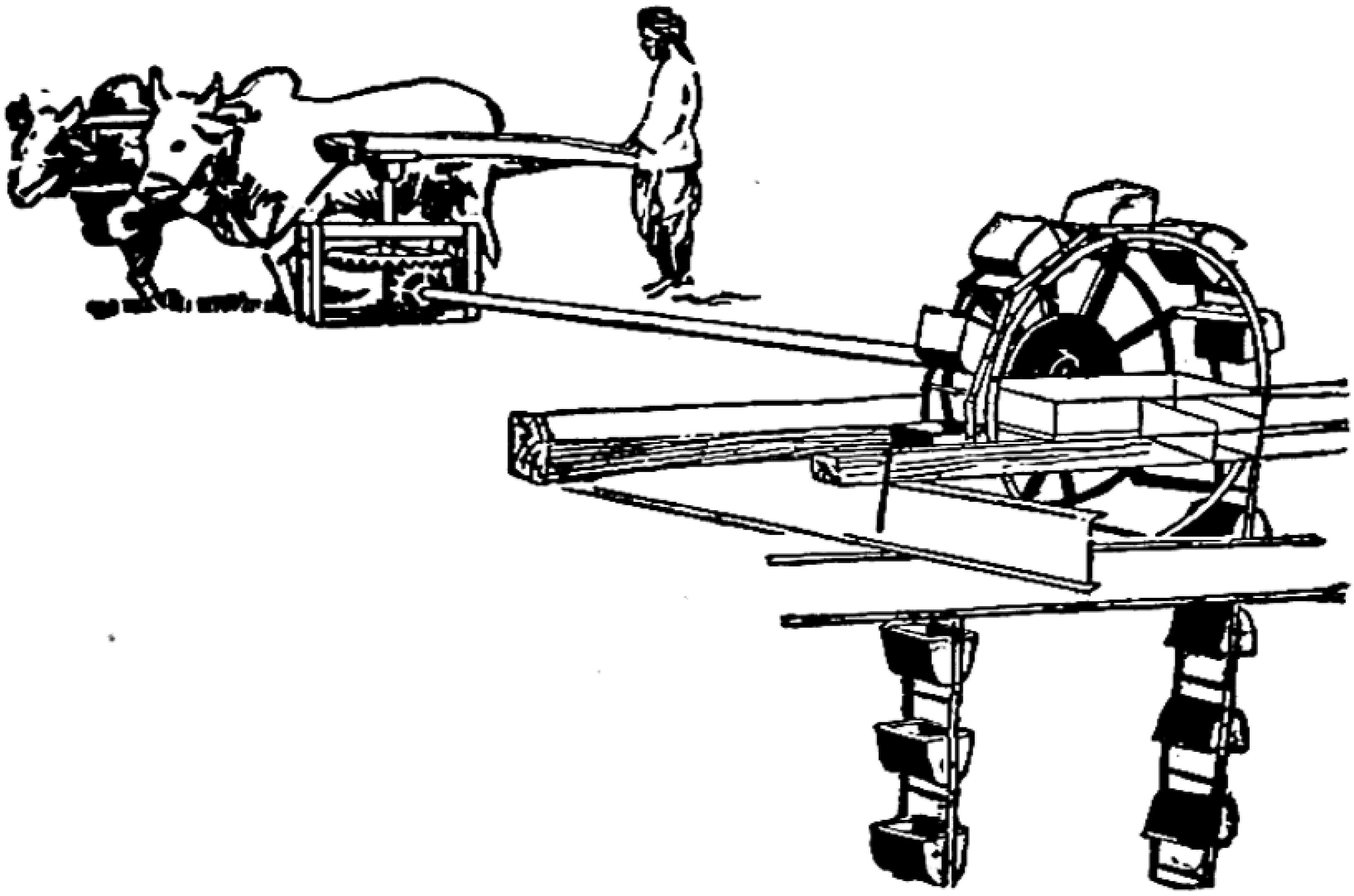
circular track, turning a large vertical drum, round which the rope winds and unwinds, as the water bucket is raised or lowered. In some, only one bucket is used but in others (the "double mhote") two buckets are used, so that one ascends while the other descends. The buckets too are different, the hose being dispensed with and a flap valve at the bottom substituted.

One lift called the "Subba Rao see-saw lift" is a combination of the *mhote* and the *picota,* the lever being a kind of platform which can work see-saw fashion on a fulcrum, like a picota, the power being supplied by the weight of a bullock which is trained to walk backwards and forwards from end to end of the platform, the up and down motion being made use of for the lowering and lifting of a water bucket, as in a mhote. In still another called "the Ramachandra lift" a bullock is trained to step on to a low trolley, which slides down on rails over a ramp lifting the water bucket in the process and then to step down and walk up for the next journey. There is much to be said in favour of the various improvements, but owing to the simplicity of the familiar old mhote, it holds the field. One exception is however the "double mhote" which can be seen used on several farms in South Arcot and Chingleput Districts of Madras.

The pulley wheel has claimed some attention and an iron (cast) wheel with roller bearings has been substituted; this certainly saves a lot of the friction and creaking usual in the ordinary wooden pulley and deserves to be adopted, although it is complained that this is liable to be stolen! One type called "Rolleasy", when tried side by side with a mhote fitted with an ordinary wooden pulley wheel is reported to have raised water at the rate of 3,200 gallons per hour while the latter could raise only at the rate of 2,700 gallons per hour, an increase of nearly 15%.

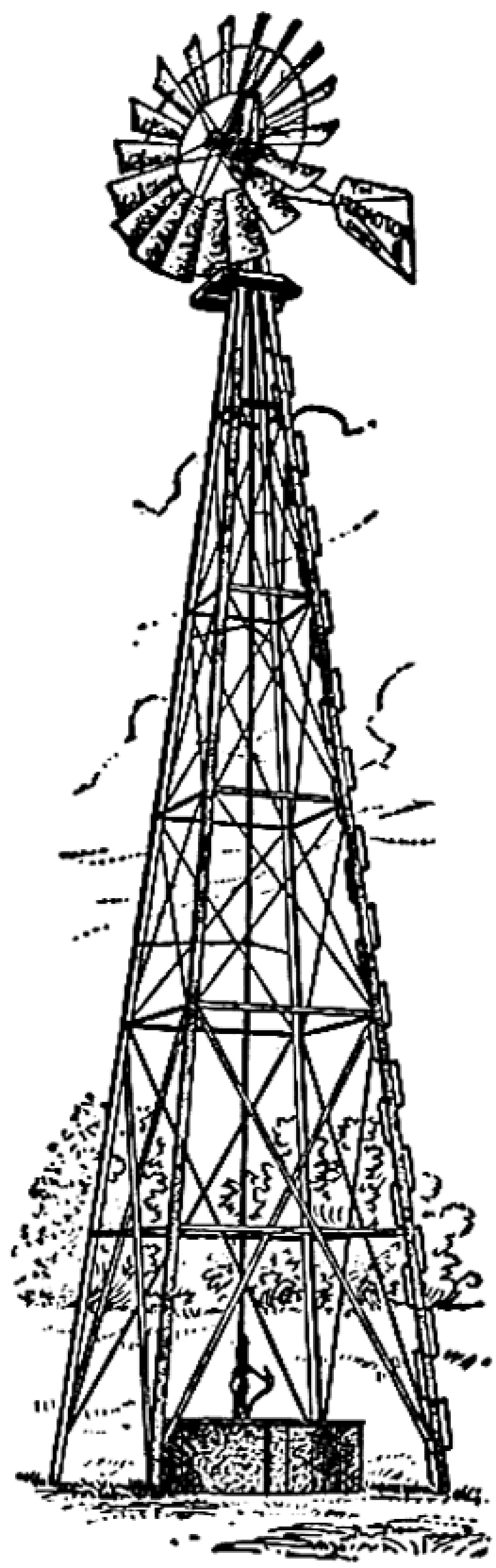
The water bucket, usually made of leather, is very expensive in these days and needs moreover frequent patching up and repair and in the water of certain wells does not last long. An iron bucket has largely come into use, the hose however being of leather as usual; but even this is replaced by canvas sometimes which is cheaper. The design of the bucket itself has been changed and the hose completely dispensed with in one model; the bucker is a large sheet-iron receptacle somewhat trapezoidal in section with a flap valve at the bottom which opens when the bucket goes down into the water and is kept shut in the full bucket as it ascends. The drawback in all metallic buckets is that they become battered and leaky, unlike the leather which is flexible and yields and can survive a good deal of bumps and knocks without much damage.

(*c*) *The Persian Wheel Lift.*—This is also a lift designed for animal power, either bullocks, camels, or horses being used. It is certainly a more complicated machine than those considered so far and in recent years has become a factory-produced machine, with all parts of suitable metal and of sturdy construction, all of which



Kirloskar "Kifayat" Bullock Rahat, or Persian Wheel type of waterlift manufactured by Messrs. Kirloskar Bros.

By Courtesy of the Company



A popular type of all-steel four post Windmill or Aeromotor, and water pump manufactured by the Aeromotor Co. of Chicago, U.S.A.

By Courtesy of the Company

therefore put it in a different class. The main points in which it differs from the picota and mhote are: (1) the lifting of the water is not in one bucket or vessel but in a series of them which are carried in a kind of endless belt or sprocket chain and the work of raising water is continuous and the flow likewise; (2) the working of the animals is on the level, using only the draft power and not the weight in addition; and (3) the mechanical means by which the circular motion is transformed into a vertical motion is through a 'sweep power' arrangement. Either one animal is used or a pair and as they walk around in the circular track they turn the horizontal wheel of the outfit which in turn engages a bevel and rotates a vertical wheel or drum with a string of buckets on it. The lift is usually low and does not exceed about 25'. Where the flow in the well is not very abundant and the level goes below the buckets then the work will have to be stopped and started again when the level is restored and the chain with the buckets can dip into the water. The capacity on a 12' lift was found to be about 3,200 gallons per hour. In the Panjab, however, a discharge of nearly the same quantity is reported to be obtained from depths of 25'.

In some recent models (like the "Noria" and similar types) animal power is dispensed with and engine power is used to turn the wheel. These models admit of larger buckets and greater depths.

Performance and Efficiency of the Different Lifts

A number of comparative trials were conducted many years ago in Madras of the work turned out by these various lifts (by Sir A. Chatterton) and the following figures were arrived at:

Name of lift	Slope of ramp	Mean lift in ft.	Gallons raised per hour	No. of pairs	Weight of animal or animals	Coefficient of utility, *i.e.*, useful work done in ft. lb. in one hour divided by weight of animals used
Picota ..	..	19·2	1952	3 men	307	1220
Mhote (Bullocks walking backwards up the ramp)	1 in 5	32·5	1110	2	774	462
Mhote (bullocks walking normally up less steep ramp)	1 in 3	35·5	3766	4	2688	497
Stoney's double mhote (bullocks walking on the level)	..	23·5	2097	2	1438	362
Subba Rao lift ..	..	18·1	1903	1	700	492
Ramachandra lift (later trial)	..	31·5	2225	1	780	92
Persian Wheel ..	..	12·4	3204	2	985	122

The Chain Pump.—This type of lift may be classed with the small-scale lifts worked by hand such as the picotas and the like. It consists of an iron pipe in which an endless chain works, carrying a number of discs which are about the same diameter as the pipe and which move practically in a water-tight manner inside the pipe, thereby carrying the water up from the well in between every two discs almost like a series of buckets. The chain passes over a wheel above the well which is turned by a handle, while below it dips in the water of the well. For low lifts it gives fair discharge but both chain and discs will need frequent repairs in order to keep it efficient. It is however very much suited to turbid water, sewage or dung liquor or drainage from manure heaps and so on, for which it is much in use on many small farms on the continent of Europe. For irrigation purposes, the work is very hard; two men are usually employed to work the pump. On a lift of 15′ with a 3″ pipe, about 2,500 gallons per hour is reported to be the capacity.

IRRIGATION PUMPS

The alternatives which are worth serious consideration, as against the various water lifts now in use, consist in the substitution of mechanical power for animal power, which is secured by the use of engine-driven pumps of different kinds. It must be pointed out that conditions are altering very materially and rapidly, so that what was not considered advisable at one time may turn out to be the reverse under the altered conditions. In the manufacture of pumps many small units are coming in, suitable even for cheaper fuels than kerosene or petrol, like crude oils, which was at one time considered not possible. Electric power has become largely available and even in India rural electrification is going on apace. Electric motors with all their well-known practical convenience can now largely replace petrol or oil-driven engines and power is being made steadily cheapter. Thanks largely to the spread of motor transport people have also to some extent become machine-wise and are able to look after such outfits, and repair facilities are also improving. There is also a growing disinclination among people to do back-breaking work and toil at the *picota* or the *mhote.* On the whole therefore conditions in India for the introduction of irrigation pumps are now much more favourable than formerly and are likely to improve steadily.

Conditions Necessary for installing Engines and Pumps

1. Among the conditions which will justify the installation of power-driven pumps, the foremost is the availability of sufficient water in the well for working the pump for a reasonable length of time at a stretch. According to Sir A. Chatterton, "the majority of wells are unable to yield sufficient water to give adequate employment to even the smallest engines" (*Lift Irrigation,* p. 168). It is therefore only the larger wells which have either a good storage

capacity or an abundant and rapid inflow, which may be found suitable.

2. There should be a sufficient area of land for irrigation and facilities for the carrying out of intensive cultivation of valuable crops. The investment on a pumping installation of even a moderate size is large and unless the above conditions are fulfilled it will not be possible to obtain an adequate return on the investment.

3. The question of how far bullock labour can be dispensed with the purchase of the maintenance of bullocks can be avoided, will also have to be considered. The keeping of bullocks for ploughing, carting and other purposes on the farm cannot be avoided and where bullock *mhotes* are in use, the farm bullocks are often able to attend to both cultivation and *mhote* work. In fact the work at the *mhote* has been found to amount to only two-thirds of that at cultivation and other farm work (in Panjab Village Surveys). It has also to be remembered that the straw fodder on the farm has to be made use of and that bullock power therefore does not cost anything special unlike engine power for which fuel (either petrol or oil) has to be purchased. Moreover, bullock power is not subject to the breakdowns that engines are more or less liable to, and are therefore more dependable. On the other hand it cannot be denied that where bullocks have to attend both to the *mhote* and to cultivation, neither work is done as thoroughly as may be necessary and the strain on the bullocks is too great. Where cultivation or the extent of the land is such as to need bullocks simultaneously at the *mhote* and the field or where, as in the case of areca and other garden crops, bullocks have to be solely for *mhote* work, it will be possible to dispense with one or more pairs, if a pumping set is installed. No unsued surplus of fodder need be feared on any farm, when the half-starved condition of the cows and buffaloes is considered whose crying need will be met at least in part by the fodder set free. In any case, the balance of advantages will generally be found to lie on the side of an installation.

4. Moreover, the ordinary bullock power lifts cannot be thought of for lifting water from depths greater than about 30′ or 35′, as already stated, and only engine-driven pumps can cope with such depths. Many important sources of abundant supplies of underground water can be located only at great depths and if these have to be utilised, then power-driven pumps will have to be resorted to. Even in the case of low-level supplies like the ordinary wells or above-ground supplies like rivers, tanks, pools, etc., from which water may have to be lifted for irrigation, the supplies, though abundant, cannot be made use of fully with bullock power, because the work can go on only for short periods and continuous work will be impossible, the need for rest for men and bullocks setting an inexorable limit. In the case of power-driven pumps, on the other hand, the work can go on continuously, both day and night, if need be, and even for days together, if so desired. The high cost of

bullocks in recent years and their scarcity even at that, is also acting strongly in favour of such installations, even where ordinarily only a bullock *mhote* will be used.

During the last few years, as part of the "Grow More Food" campaign in all the States, great encouragement is being given by the Government in many ways to do installation of pumps and engines for irrigation. Many hundreds of such outfits have been installed and the demand, as a matter of fact, exceeds the supply. This aspect of the campaign, it may be remarked incidentally, will certainly be its most important and beneficent legacy. Conditions have thus vastly changed and continue to change in a manner which demands the introduction of pumps and engines and it is no longer a case of having to justify their use.

5. Considerations regarding the site for the installation with reference to the well, tank or river side are also very relevant and will have to be carefully looked into. Pumps have to be installed fairly close to the water level, as the suction height should not exceed about 25′ and should preferably be much less, say 15′ to 20′; the level of the water may often fluctuate within wide limits, sometimes submerging the pump and sometimes (perhaps rarely) going below the foot valve. The location of the pump and the motor may both present difficulties at the site where they may be required and may even make it too costly. Competent engineering advice on this and other allied aspects is essential before a decision is taken.

Kinds of Pumps.—There are many kinds of pumps and the choice of the type, the capacity, the nature of the motor or power and the method of installation according to each particular condition, are matters on which the advice of engineering experts should always be sought. A few points of general application may however be mentioned here.

Pumps may be of (1) the piston or plunger type, (2) the centrifugal type, (3) the rotary type. All these types make use of the suction principle, that is, exhausting the air in the suction pipe and making the water rise into it and occupy the vacuum. This circumstance makes it imperative that the pump be fixed only within the suction limit for the country, which depends upon the elevation of the tract above sea-level; as already stated this is within 25′ under ordinary conditions. The piston pumps create this suction and work the pump by means of pistons moving up and down inside the air-tight pump barrel, which are provided with valves of one type or another (flap, ball or poppet). In the centrifugal type the same effect is produced by vanes or 'impellers' which rotate inside an air-tight casing; the water enters by suction through the suction pipe which opens into the casing by the side at the centre and is forced out by the revolving vanes by centrifugal force tangentially through the delivery pipe at the periphery of the casing. In the rotary type, two toothed wheels or gears which mesh very

closely rotate inside a similar casing; the water is sucked up when the gears disengage over the suction pipe and produce a partial vacuum, and is forced out when they engage or mesh together, under the delivery pipe. All of them are 'force' pumps, *i.e.*, they not only raise the water into the barrel or casing to the suction height but also force it up to the height required for irrigation. They have therefore three essential parts, the suction pipe, the barrel or casing and the delivery pipe. Nearly all of them are also provided with an "air chamber" for effecting a continuous flow. The vertical height to which the water has to be raised is the 'head' and including the suction height makes up the total head to which it has to be raised. In addition, there is the resistance due to the friction in the pipes which has to be overcome and this depends upon the diameter of the pipe, its total length, the number of bends or elbows and the velocity of the flow of the water in the pipe; this friction is also expressed in terms of the 'head' and has to be added to the two heights of suction and lift; the power required for the whole work will be calculated according to this total lift. The narrower the bore of the pipe, the more the length, the more numerous the bends, or the greater the velocity of the flow, the more is the friction. In addition to the delivery pipe, barrel, casing and suction pipe, another important part is the foot valve and strainer, fixed at the lower end of the suction pipe which is below the level of the water. Water, turbid with much sediment, is likely to contain grity particles which will wear the valve seatings and the vanes and pistons and make them less airtight and efficient. The centrifugal pump is less liable to this drawback and is therefore more suitable in such cases. It is indeed the type largely used for irrigation. A good strainer kept well cleaned and in repair will avoid this risk. The smaller units usually consume greater power in proportion to the work done and are less economical than larger units. Motors and engines are usually recommended to be of a higher power than may be necessary for the particular capacity of the pump to be installed, so as to possess a good margin of reserve. In the case of electric motors and centrifugal pumps, many units are directly coupled together and form one combined unit fixed on a single platform, and these are suitable where the level of the water in the well or other source does not fluctuate much. More generally however pump and motor or engine will have to be fixed separately from each other, the motor or engine at a considerably higher level and housed suitably for the belt drive and for strength and stability. Most centrifugal pumps are of the horizontal type, *i.e.*, in which the vanes move in a vertical plane and are mounted on a horizontal axis; but some are of the vertical type, *i.e.*, in which the vanes move in a horizontal plane around a vertical axis. These latter are used in very deep well pumping and the pump remains submerged in the water. In bore-wells and tube-wells also, the pump barrel (of the piston pump) remains submerged.

Power Used for Pumps.—The power used for driving irrigation pumps is furnished by (1) steam; (2) oil, petrol or charcoal gas, in internal combustion engines; (3) electricity; (4) (to a small extent) the wind. (5) There are many modern types of pumps which are worked by compressed air, as the direct power for forcing up the water, one or other of the above being used only to work the air compressing machinery.

1. The steam engine is used only in the case of very large pumping installations, irrigating perhaps hundreds of acres. Many of the large water companies in California, which pump water from great depths and supply it to hundreds of acres of orchards or other crops use the steam engine, the furnace usually burning crude oil. In India they have the advantage that the fuel is locally and easily available; they are moreover not subject to the breakdowns usual to electric power plants, possess less complex and more easily replaceable parts and do not generally require the same high degree of technical knowledge in running and attending to repairs and breakdowns.

2. The internal combustion engines provide both large and small units; the smallest ones use petrol and the larger ones either kerosene or crude oil. The crude oil is of course the cheaper fuel and though it was confined only to large units at one time, many smaller units have also in recent years been designed and have come into use, which work on crude oil. The majority of pumping installations use in the internal combustion engines, all but the larger units using kerosene.

3. Electric power is of course the most convenient one; the pump can be started working in a moment when desired, by merely switching on the current, unlike the steam or the internal combustion engine. It is also the cleanest to operate. There is also the advantage that it does not depend upon an imported article like petrol or kerosene, supplies of which are subject to stoppage and even when available have to be brought long distances from towns to the pumping site in the village. Power is also being progressively cheapened and made available over a large extent of country. The drawbacks are that it forms part of a general centralised system, breakdowns in which affect the individual user also and that it is available only in particular parts of the country and even there only in the proximity of power lines.

A very noteworthy example of the extensive use of electric power for pumping purposes is furnished by the tube-well irrigation system in the U.P. Tube-wells, both large and small, in very large numbers have been put down, which pass through a great depth of the Indo-Gangetic alluvium and furnish abundant supplies of water. Most of these are operated by electrically-driven pumps under an extensive system of current distribution and the Government-owned wells supply water in a well regulated manner in the same way as canal water is given.

Cost of Power.—The following figures regarding consumption of power in respect of each of these sources of power per horse power-hour and cost (at current prices) in Bangalore will be found useful in this connection :

Source of power		Consumption and cost per horse power-hour	
Steam engine	..	4 to 5 lb. of coal or	13 to 14 pies
		7 to 10 lb. of wood fuel (casuarina)	about the same
Oil engine	..	·7 to ·8 lb. of kerosene oil	15 to 16 pies
Crude oil engine	..	·6 to ·8 lb. of crude oil	10 to 12 pies
Diesel oil engine	..	·37 to ·5 lb. of diesel oil	9 pies
Suction gas engine	..	1·5 to 2 lb. of charcoal	15 to 18 pies
Electric motors	..		1 anna per Kilo-watt hour or 9 pies per horse power-hour

4. The wind as a source of power for irrigation pumps is also utilised to some extent; it is obviously the cheapest source of power, as it costs nothing practically to run, except what may be required to keep the machine in good working order. The most extensive and well-known example is furnished by the wind mills of Holland, where they pump out sea-water from behind the dykes. Great improvements have been made in the design and construction of wind mills, in respect of the height and strength of the towers, the vanes and their automatic adjustment to the speed and direction of the wind, safety devices and so on. Their working is obviously intermittent and some kind of a storage tank will have to form part of it. The power developed is generally small (usually about 1/3 to 3/4 H.P.) and it may be doubted whether they can be of service in irrigation, although for domestic or garden supply or for drinking water for animals on the farm, it may furnish a sufficient supply. Aeromotors for irrigation pumps have been studied by Sir A. Chatterton, and the results are published in his book on "Lift Irrigation". According to him, the velocity of the wind is such, at least in South India, that it can be usefully employed. A wind velocity of not less than 8 miles per hour and up to 11 miles will be sufficient to make a 16′ windmill quite useful for the purpose. A 12′ American Aeromotor with which he worked and which was mounted on a 70′ tower raised (under the conditions in Madras City) on an average 30,450 gallons of water per day, with a minimum of 12,040 gallons per day, taking the work throughout the year. This is not insignificant, as it is equivalent to the supply which may be expected from an ordinary *mhote* working for 10 hours. He would advice however that mills should be geared to two or even three pumps, to suit them to increases in the wind velocity and to obtain a greater output and that moreover the present models should be made stronger and improved in other respects also. The comparatively small output, together with the

complexity of installing and working these machines and the fact that the supply cannot always be had when wanted, etc., all account for the appliance not having come into much use even in South India. In other parts of India the wind velocities are seldom sufficient for these motors (*see* also Chapter I for Wind Velocities in India).

It has been suggested that the wind power of the aeromotor should be used to generate electricity by driving a dynomo, that the electricity should be stored in a suitable number of storage batteries, and that this electric power should be used for driving pumps. There used to be some vogue in the remote countryside in the U.S.A. not served by electric power, for generating and storing power in this manner and using it for lighting in the houses and barns, but even this has been only a temporary makeshift which has disappeared with the well-nigh universal supply of electric power by Corporations. The fact that wind power costs nothing is certainly a valuable and tempting feature and its utilisation in India in one way or other deserves further study, especially as the above study by Sir A. Chatterton is now nearly 50 years old and conditions are much changed since then in India.

Power required for pumping.—The horse power required for pumping up the required quantity of water to any particular height may be calculated as follows: Multiply the total head in feet (suction height + height above pump to be lifted + friction head) by the weight in lb. of the water raised per minute, *i.e.,* the capacity of the pump (gallons multiplied by 10) and divide the product by 33,000. This figure will give the actual H.P. but in order to cover loss in power and to afford an ample reserve for possible overloads, it will have to be doubled. The friction head is a varying figure but in the case of a 2″ pipe and a pump capacity of 6,000 gallons per hour it may be reckoned as 45 for every 100′ length of pipe used. If the pipe diameter is 3″ then the head will be only $5\frac{1}{2}'$ per 100′ of pipe.

The "Hydraulic Ram".—This machine is a device for lifting water, which comes in a separate class; it is not a pump like the ones described so far, depending upon the suction and upon some form of power for lifting the water. In the hydraulic ram the force of running water with sufficient force or fall is availed of to raise a portion of itself to the desired height; all that is required is therefore a stream with a suitable fall. A good running stream at the bottom of a valley for instance can be utilised to raise and deliver water to a house higher up the slope, or an irrigation channel with sufficient fall may be utilised to force water up to irrigate land on the upper bank of the channel, which is not commanded by it. The fraction of the water lifted up will depend upon the fall and the height lifted (modified by friction of the pipes, etc.); the proportion of the water lifted to the water flowing will be as the fall to the height lifted. For example, with a five-

feet fall and a 30′ height of lifting, the volume of water lifted will be 5/30 or 1/6, as a theoretical maximum, but due to friction of pipes and valves may be less, about $\frac{1}{8}$ roughly. Once it is installed there is no running cost of any kind except the renewal of the valves once a year or in two years and hardly any attention to be paid. The flow is continuous all through the day and night, and day after day, as long as the stream or channel is running. A storage tank usually of cement-lined masonry and large enough to hold at least one full day's inflow of water should form part of the equipment, so that water may be drawn only when wanted and not be flowing indiscriminately and wasted. The tank is constructed, of course, at a spot high enough to supply water where wanted, by mere gravity flow. It is a cheap, efficient and conveniant form of living water. For domestic water supply in places like the coffee estates or for irrigating land lying higher than the channel in the channel tracts, for example, it deserves to be introduced.

Control of Irrigation

In order to secure the full advantage of the facilities for irrigation not only must the other factors of production like manuring, drainage, pest control, proper varieties of crops, etc., be assured but it should be possible to control or regulate it according to the needs of the crop at particular stages of its growth and to any special requirement necessary. In the case of the semi-irrigated garden crops, irrigation water will have to be given at definite intervals which will allow of the 'break necessary for weeding, hoeing, the aeration of the soil, application of manure and so on; it must also be seen to that such interval is not too prolonged and that the watering when restored is full and ample. Even in the case of a crop like rice, although normally watering may be continuous, still the quantity required and most favourable at particular stages is not always the same and will have to be regulated. When rice is cultivated in puddle by the broadcasting of dry seed or sprouted seed in puddle, water has to be regulated for the sprouting very carefully, putting it on or withdrawing it or reducing or increasing it, during the stages of sprouting, rooting of seedlings and stretching or lengthening of the stems by growth. To a certain but lesser extent this applies to transplanted rice also. There may arise special occasions for draining the water out, as when moss or other aquatic weeds have to be kept down, or water to be retained and kept without overflowing when manures are applied to the growing crop, or kerosene oil treatment is undertaken to check the 'case worm' and other pests. Similar draining will be required as the crop reaches full maturity and harvest has to begun. The surface of the puddled field has also to be kept intact without being subjected to wash or disturbed by a rapid overflow.

Such control is possible to the fullest extent only in the case of well irrigation. Water can be applied exactly at the time needed

and stopped or continued as may be desired, the quantity also regulated as may be deemed necessary. Both well and land are under a single ownership and the fields are also nearly always on the flat and level. At the opposite end, comes the irrigation from channels, especially the contour channels where the fields lie in numerous terraces one below the other with the channel at the top traversing the upper slope. Under this condition water has to be continuously flowing in the channel and flooding every field from the top to the bottom of the slope. No owner of any fields whether on the top or at the bottom of the series is a free agent and water can neither be cut off or applied at will, without seriously infringing the right of a holder of land above or below. Water is usually allowed to flow continuously, from the channel into the upper fields and from them to the fields lower down, overflowing from one to the other step by step. There is furthermore a continuous wash of both soil and manure, from the top fields especially. Owners are not free or independent to vary according to their will or convenience the times of the various operations, such as preparing the fields, sowing or transplanting, or harvest, but have to conform to a uniform time-table. In between the two, comes the irrigation from tanks or channels in level country or the deltas where some measure of independent action is possible and the risk of loss of soil or manure does not arise. These facts have a bearing on the yield of rice under the different sources (other conditions being equal), the yield under well cultivation is usually the highest, and the yield in contour irrigation channels lowest and those from the tank and level deltaic channels are intermediate.

CHAPTER VII

DRAINAGE

SOILS may be rendered less fertile or even quite unsuitable for cultivation owing to the presence of excessive water. This excess of water may be present underground within the root range of ordinary crops or may be even so great as to cover the surface of the ground in addition. Such excess of water has to be removed by appropriate means, in order to make the soil suitable for cultivation. This process of removal of the excess water is known as drainage. The process is in fact the reverse of irrigation.

SURFACE WATER

1. Excess of water on the surface itself generally occurs in the tracts of heavy rainfall during the rainy season and in areas near to rivers likely to overflow and flood the fields. Both kinds of excess water are more or less temporary and may disappear after the heavy downpour ceases or the flood abates. Even this temporary condition will damage practically every crop, with the exception of rice. Water may stand in the fields for several days from a few inches up to even a few feet, depending upon the flood and the nature of the country. Some crops may revive with only a temporary check in the growth, but others may be permanently ruined, under such conditions.

2. Other conditions of such excess of water will occur in the case of serial tanks, where the catchment of one tank forms the irrigated area of the tank above; during seasons of heavy rainfall, water from the lower tank will back up, submerging more or less of the tail end area of the cropped land above.

3. Large areas of low lying land may also receive the surface flow of the surrounding high lying land and become one sheet of water which may lie on the land for varying periods.

4. In coastal flats, especially on the Malabar coast, large areas of flat rice land remain submerged during the south-west monsoon and cultivation becomes possible only after the water is drained away. In certain countries like Holland and the fen country in Eastern England, the sea itself has to be kept out, not only during high tide but also as a normal every-day need.

These cases of flooding by surface water are guarded against and kept down by various methods such as (1) diverting the flow by means of suitable channels, away from the cultivated land; (2) by keeping back the water by erecting small embankments as in the case of the serial tanks mentioned above or very large ones almost like walls as in the case of sea walls or dykes, according as the particular conditions may demand; (3) by actual baling or pumping out; (4) by a regular system of open drains or cuts

in the surface of the field or garden itself, sometimes combined with a suitable layout of elevated beds, which though resorted to generally as a measure of draining out underground water, is adopted in the regions of heavy rainfall like the malnad mainly for leading out surface water itself; and (5) by a combination of two or more of the above methods. All these methods are in general adoption and can be seen in the tracts where such conditions prevail and are worth close study for application in similar situations. Where the country is undulating, it may be easy to divert water and to lead out the surface drains lower down; but where the country is flat and low lying, the difficulty as to where and how to lead out the surface water will arise. Except on the coastal flats at or below the sea-level, where expensive schemes of pumping the water back into the sea, lagoon or into artificial temporary canals are generally adopted, it will be possible to arrange for some sort of a moderately efficient outlet at least. This difficulty regarding the securing of an outlet is common to both surface water and underground water and will be referred to further on.

Excess of Underground Water

The second and more general condition where drainage becomes necessary arises from the accumulation of water below ground and within the root range of crops. It is as a matter of fact with this condition, that methods of farm drainage largely and almost exclusively deal. In humid climates as in many parts of Europe and America, the need for this kind of drainage is present in ordinary cultivation (rainfed or dry as it is called in India). In the tropics and sub-tropical countries and in the arid or subarid tracts of the world, however, such a condition arises generally only under irrigated cultivation, principally under tank and canal irrigation, and generally on the flat and fertile deltaic tracts.

This excess of water below ground arises on account of (1) stiff or clayey soil, through which water drains only with difficulty; (2) similar soil underneth in the lower layers or subsoil, which holds up the water in the upper layers; (3) the rising of the water-table or level of the underground water, on account of the percolation of water from a tank or canal carrying water, much above the level of the field; (4) underground water being held up, on account of the basin-like situation of the land, or even on a dead level, without facility for any movement of soil water to a lower level. In many cases, two or more of the above causes may be present and be responsible for the excess water.

How Lack of Drainage Becomes Harmful

(*a*) *Shutting out of Aeration Leads to Poor Growth and Crop Diseases.*—The harm which results to crops on account of lack of drainage arises chiefly by the shutting out of air from the pore spaces in the soil within the root range of the crops, which in a badly drained

soil are filled more or less completely with water. Proper aeration in the root zone is necessary for the healthy growth and normal development of all crops, including even rice, which may not appear to be in need of it. Indeed aeration in the root zone is as necessary for plant life as respiration is for all living organisms, and when the air is shut out both poor development and crop diseases are the result. A pale green or sickly yellowish colour of the leaves and dwarfed growth are common signs of bad drainage. Red rot in sugarcane, leaf and boll shedding, etc., in cotton, wilt in indigo and other diseases are directly traceable to lack of drainage. Aeration is also required for the chemical and bacteriological changes due to oxidation which are concerned in the production of available plant food in the soil. In the apparently water-logged condition of rice cultivation such aeration is provided by the dissolved air in the irrigation water, which moreover has to be freely passing through the soil and not merely stagnating on the surface. On the contrary, in imperfectly aerated soils, deoxidative changes may take place and under certain conditions products which are poisonous to plant growth may even be formed. Aeration is indeed held by some to be even more important than plant foods or manuring, but whether this is true or not, it cannot be denied that aeration will enable the crop to make better and fuller use of the plant foods.

(*b*) *Surface or Shallow Rooting.*—Roots will cease to grow and develop into such moisture saturated layers and tend to remain largely near the surface, like surface feeders and be subject to wilting for lack of moisture when the surface becomes dry even though there may be more than enough moisture down below.

(*c*) *Salt Accumulation.*—In soils which may contain much soluble salts, these are not washed down and away from the root zone, for lack of sufficient percolation and drainage, but tend to accumulate not only below but also in and near the top soil itself. The level of the underground water in fields commanded by tanks and canals keeps rising (as already explained) and salt-laden water comes to the top layers where the water evaporates and leaves the salts in the soil; such a process repeated year after year makes the soil too concentrated in salts to be suitable for cultivation. This in fact is one of the main causes for the occurrence of alkaline soils, and for the main trouble in many areas under canal irrigation, and especially where irrigation has been newly introduced. For the same reason the provision of adequate drainage is the most effective way for the reclamation of such soils. The accumulation of the salts also makes the soil itself more and more difficult to drain, by the pasting effect they have upon the soil particles. Although it may be possible to grow crops where the alkalinity is only moderate, the quality of the produce may suffer; for example, when sugarcane is grown the jaggery may not set firm, may sometimes taste salty, and if sugar is manufactured the outturn will suffer. If these alkaline soils are naturally clayey, then dangerous swamp conditions may develop, and

the soil itself becomes a sort of floating mud, on which even walking may be impossible.

(*d*) *Lowering of Soil Temperature.*—The soil temperature is much lowered in soils which lack drainage and under such conditions these soils are sometimes called "cold" soils. This aspect of the matter assumes much importance, in cold countries, where the need for adequate warmth is very much felt and the lack of it becomes a serious disadvantage. In such 'cold' soils, germination is much delayed and the growth later on is both stunted, sickly and poor. The difference between the interior of badly drained soils and outside, is reported to be sometimes as high as 12° F. The lowering of the temperature is the result of the cold due to the evaporation of the water, and the greater heat required to warm up a wet soil, as against a dry soil.

(*e*) *Marshes.*—Where lack of drainage has become a permanent feature, the land simply becomes a marsh and unfit for cultivation. Only certain kinds of rank special vegetation natural to such conditions can be found, with its appropriate natural fauna, in such regions.

METHODS OF DRAINAGE (*a*) OPEN DRAINS

1. *Temporary Drains for Individual Fields.*—The chief and almost the only way by which the drainage can be improved consists in lowering the level of the water-table or saturated zone in the soil. This is secured by the opening out of a series of drains, ditches or open cuts in the ground at regular intervals in the area, about 3′ or 4′ in depth. These cuts relieve the congestion immediately, and water from the soil and subsoil flows into them instead of raising up and saturating the upper layers near the surface. Such open drains are cut both within the fields and around.

In the tracts of very heavy rainfall like the malnads of Mysore and the region of the heavy south-west monsoon generally the cultivation of crops other than rice can be carried out only under a special method of growing them in elevated beds, which are divided by open trenches. These trenches are fairly deep and permanent in the case of the areca gardens but are shallow and temporary in the case of other crops like sugarcane, ginger, yams, pulses, etc. During the rains these drains run like streams carrying the rain-water out and preventing it from floodding the crop rows. Such beds may be from 3′ to 6′ broad from centre to centre and about 1′ to 3′ high from ground level or from 2′ to 6′ from the bed or bottom of the drains. Suitable outlet through a large main drain is also provided in order to receive the outflow from the smaller or field drains. The dual purpose lay-out of the areca gardens with a view to meeting the needs of drainage in the rains and of irrigation in the rainless months is a very efficient and ingenious one.

2. *'Cut Out' Drains.*—The inflow of underground water from a tank or a canal above the field is cut out by interposing a drain

parallel to the bund and between it and the field. On a small scale and for individual owners this will afford considerable relief, and indeed, in the way in which the fields are scattered under any irrigation source, whether tank or canal, under different ownerships, little more will be possible. It is only a temporary expedient, but for the duration of one crop season, will be found tolerably sufficient. Of course the drains will become eventually so full of water that they will cease to be effective in lowering the level of the water in the saturated zone in the cultivated strips of the field. As however the inflow of water and irrigation cease after the cultivation season of a few months, this risk is not great.

3. *Permanent Drains.*—As a permanent measure however, arrangements have to be made for the leading out of the water from these drains away and to a much lower level altogether. For this purpose it is necessary to have a common main drain sufficiently deep and wide, for the whole tract concerned into which the individual field drains can flow freely. Such a main drain will generally lie in the deepest part of the valley line and special arrangements will have to be made for laying not only a main drain but also a number of sub-mains which will connect with the field drains of the individual fields and open into the main drain. Both the main drain and the minor drains must of course have the necessary slope, so that water from the latter may drain easily into the former, which in its turn should carry the drainage freely. The whole arrangement will have to form part of a regular scheme of drainage for the area concerned, which under the present conditions of different and scattered ownership of the fields is beset with many difficulties. In Mysore (and probably elsewhere) there are many tanks which belong to single owners, though the fields may be cultivated by different tenants and it cannot be very difficult in these cases to arrange for a well-laid-out system of drains, making use of the *kodi hulla* or overflow stream or ditch as the main outlet drain.

In the case of lands irrigated by the different river channels, especially in Mysore, there should be no difficulty for suitable outlets, because the whole irrigated area drains into the rivers steeply rather than otherwise. The irrigated area is situated between the channel on the high level and the river below, hugging the banks of which the irrigated stretch runs throughout its length. The difficulty in the older areas already under cultivation will arise from the different or fragmented ownership of the fields as stated above. In areas to be newly brought under irrigation, the trouble will have to be guarded against in advance by making adequate provision for a system of drains along with the irrigation channels, both main and subsidiary.

It is on land which is flat over a considerable extent, that drainage ditches will not have the necessary fall and the flow will therefore be very slow and that the outlet required for leading out

the water will be difficult to arrange. Still in many parts of the world, even on such tracts extensive drainage is arranged for, such as in the cultivation of sugarcane in Java and in Lousiana, in the U.S.A. In the latter state, the drainage extends over many square miles there being a drain 3′ × 3½′ for every 120′, with cross drains 5½′ × 4½′ for every 3 to 5 acre section and a main drainage canal 30′ broad and 12′ to 14′ deep for every 500 acres!

(*b*) UNDERGROUND DRAINS

Drainage can be provided by means of underground drains, which perform the same function, *viz.*, prevent the rise of the water into the soil by making it to percolate into themselves, just like the open drains. These underground drains afford the great advantage that the surface of the field is not cut up and much valuable space taken up, as in the case of the open drains, and cultivation operations made more difficult; on the other hand, they are costly to lay. Underground drains may be (1) pipe drains, (2) box drains, (3) rubble (or other coarse stone or gravel-filled) drains.

1. *Pipe Drains.*—The pipe drains also called 'tile' drains are made up of sections of unglazed earthenware pipes about 3″ in diameter and about 12″ to 18″ in length, laid down in such a way that the ends fit closely together or into each other, and the whole length forms a continuous pipe. A number of such pipes laid at regular intervals at distances which may vary with the nature of the soil may connect with a slightly larger pipe running at a slightly lower level and forming a main drain; or the latter may be only a submain and two or more of them may in their turn connect with a still larger pipe which will then form the main drain. This main drain will carry the whole drainage from the field, collected from the submain and its branches the laterals, out through a main outlet into a stream at the lowest end out of the area altogether. The laterals are laid usually at a depth of 3′ below the surface with a gentle slope (2″ in 100′); the submains come at a slightly lower level to receive the flow from the laterals and the main again at a still lower level. The laterals may open into the submain from both sides (but not exactly opposite each other) somewhat herring bone fashion or on only one side, as may be desired. It may not be always possible to have such an elaborate system; a set of small pipes (laterals) may be laid so as to open into a common drainage ditch at the side and if the ditch is kept in good repair and the flow of the drainage water not interfered with in any way, even this arrangement may be found satisfactory.

The drainage water enters the pipes both by percolation through its pores along its length and by direct seepage into it at the joints. Sometimes reliance is placed on the latter alone and less porous pipes almost like glazed sewage pipes are also used. Ordinary potter's earthenware pipes which can be made in the villages are found quite

effective, though it may not be quite so lasting as the more costly pipes.

Distance between Drains.—The distance between the lines of pipes or drains will depend upon the permeability of the soil; if it is not very stiff a distance of about 30′ may be allowed, but otherwise a distance of 12′ to 20′ will have to be allowed. Obviously pipe and underground drains can be laid much closer than open drains, as the latter under the same conditions will reduce the space available for cultivation and also interfere very much with the cultivation. In India there has not been much underground drainage attempted and one has to rely only on foreign data.

2. *Box Drains.*—Instead of the pipes described above, underground drains may be made in the shape of a V-shaped cut or trench, the sides of which are riveted with stone and the top covered over with stone slabs and the whole covered over with soil, restoring the surface of the field. These are also made of about the same depth of 3′ below ground, about the same distance from each other as pipe drains and given the proper slope to ensure free flow into a main ditch. Though generally similar to pipe drains they do not lend themselves to the elaborate ramification of the pipe system; it is however worthy of adoption wherever facilities for stone exist and will be found suitable for individual fields, which may have an adjoining open ditch to receive and carry the drainage water.

3. *Rubble Drains.*—A somewhat equally poor substitute for pipe drains is made by cutting narrow drains V-shaped or rectangular in section, as for box drains, filling them up with rough stones large and small and then covering the whole up with soil level with the surface of the field. The method is tantamount to the laying of a long core of permeable material underground in the zone to be drained, through which the excess water may drain and be removed. These field drains should of course open and discharge into a good open drainage ditch with a suitable slope to ensure free flow. Instead of stone and rubble, even jungle wood loppings, date stems, brushwood, and such material may be filled in and covered over. All these are however very poor substitutes for good serviceable pipe drains and may choke up with soil and fail to run after some years. The author has however seen rubble drains underlying sugarcane fields, functioning even after the lapse of many years probably fifteen or twenty. The need in certain tank-fed areas for drainage is really great (at least in Mysore) especially for growing sugarcane and the benefit of drainage is so striking that drainage even by these crude materials is worth attempting. On the Hebbal Farm in the Mysore State, the sugarcane fields were underdrained by ordinary earthenware potter's pipes in a simple manner, but the effect was so great that the location of the lines of pipes underground could be made out by the particularly tall growth of the cane rows directly over them, in contrast with a lesser growth in between the lines.

Depth of Drains

In deciding the depth at which the drain pipes or other material as in the case of the box and rubble drains should be laid or to which in the case of open drains they should be dug, it should be remembered that the drains act by intercepting the rise of the underground water and preventing it from rising up, *i.e.,* by lowering the water-table. At the same time they should be deep enough not to be disturbed or damaged by the implements of tillage and also to allow a sufficient depth of soil above them for the needs of the roots of plants. For these purposes it is found in practice that a depth of 3′ will have to be given, a greater depth being hardly necessary for the reduction of the water-table and a smaller depth being found too little for the needs of the crop and cultivation. While this is the depth for the field drain or laterals, the submains and mains should of course be deeper, but even then the deepst drain which will be the main, need not be more than 4′ as a maximum, the submain having an intermediate depth.

Outlets

The finding of a good outlet for the drains to discharge into is generally a rather difficult problem and it is very much so in flat country. This difficulty arises whether it is open drainage or underground drainage which is proposed. If the level of the tract is not favourable for the leading of the drainage water outside by mere gravity flow, then it will have to be pumped out from sumps, wells or large pits into which it may be flowing, so that by frequent pumping out, the level of the water in the sump may be kept low enough for the drainage to flow into it. If the need for drainage should be so very great, then even this costly measure will have to be considered. The water pumped from the sumps will have to be led out through pipes to a lower level far down the course of the canal, or pumped on to, higher ground not reached by the canal water, such as pastures, tree or other vegetation. As a temporary and somewhat palliative measure the cultivation may be carried on by laying the land into large ridges divided by furrows, so that the root zone of the crop will be a little clear of the water saturated soil below.

Utilising Drainage Water for Further Irrigation

In this connection the question whether and how drainage water can be utilised for further irrigation may be considered. In the case of surface flow, irrigation water in the contour channel irrigated tracts where water flows down from terrace to terrace, it is the general practice to pick up the water at a lower tank or channel and to use it for irrigation again and to repeat the process, if possible, until the river or stream draining the region is reached. Such water is different from drainage water proper, because it will not be charged with the salts dissolved out by the drainage water from the lower layers

of the soil, to anything like the sarne extent. The nature and quantity of such salts will of course depend upon the salts present in the soil and may possibly render the water unsuitable for irrigation, unless largely diluted. Such dilution will happen when the water flows into and mixes with the canal water lower down and in that case become diluted enough for further use; but whether it can be used as such without dilution is difficult to say. In at least one sugarcane farm in Mysore the author is aware of drainage water from underdrained sugarcane fields being collected in large wells and pumped back again to sugarcane fields lower down. Such utilisation deserves trial and if it is advantageous elsewhere without any harmful effect then it solves the difficulty of securing suitable outlets and also conserves valuable irrigation water. The author is also aware of an orchard where such underground drainage water was used for further irrigation by a rather original method, a general unthriftiness resulting in eventual dying out of many trees, has been observed. Although it cannot be definitely stated whether the drainage water was responsible for the result, it seems necessary in such cases that a decision should be taken only as the result of trials.

Composition of Drainage Water

The composition of drainage waters will of course give information as to whether they may be used directly for irrigation.

The matter becomes important only when the soil which is drained contains much alkali; as a matter of fact washing out of the salts contained in the soil by surface flow and through underdrainage is the only satisfactory method of reclaiming alkaline lands and such drainage water therefore may contain total salts in excess of what may be safe for irrigation. Whether the drainage water be from alkaline soils or from ordinary soils, it will be advisable to find out the salt content before deciding to apply it for irrigation. On page 88 (in Chapter on Irrigation) are given figures regarding the safe limit of total salts for use in irrigation. If the salt content is really high and if such salt-laden waters should be used at all, then some kind of pre-treatment, such as with gypsum, will have to be adopted in order to make it safe for irrigation, or commonly the water allowed to flow into the canal itself lower down and become sufficiently diluted.

Care of Drains

Drains, both open and underground, are subject to damage and should therefore be carefully looked after and kept in repair. Open drains become silted up both by earth washed down and by the earth from the sides falling in; they should be kept deepened to the original depth, the sides sloping and well tamped and, if possible, turfed over. Field rats and crabs burrow around and under the pipes, which may sink; outlets may be blocked with loose earth and vegetation. Trees from the close proximity of the field or margins

may send out fine rootlets into the pipes, where they may grow so much as to plug the pipes. All these defects should be attended to promptly and repaired, in order that the drains may flow properly. Where large-scale and systematic underground drainage is carried out, manholes are provided here and there and a correct plan of the lay-out indicating the location of the pipes is also maintained, both of which are helpful when repairs have to be made.

The extent to which large-scale and expensive underground drainage is carried out in certain countries may be judged from the following two examples given by Prof. King, *viz.,* (1) six square miles of land in Illinois in one block were drained in this manner, and (2) another area in the same State was also drained likewise in which the open ditches which were to receive the flow from underground drains measured 70 miles in length!

Drains in Dryland Cultivation

Although it is only under irrigated cultivation in India that the need for drainage largely arises, and special methods such as those described above have to be adopted, even in ordinary rain-fed (or dryland) cultivation it may be necessary under certain conditions to resort to drainage. These conditions will arise where the soil is highly porous containing a large admixture of coarse sand and especially in rocky and boulder strewn situations. The soil in these cases not only fills rapidly but also remains wet and saturated for a long time, as it is held up by the nature of the ground. Many such pockets can be met with and it is usual to sow these patches with coarse upland rice, instead of the usual dry crops, because the latter may suffer. On these soils a few long narrow trenches, almost like wide plough furrows, at short distances will quickly reduce the excess of water, which will flow into these drains. The need may arise in the middle of the crop season when the crop is on the land; then these trenches will have to be dug through the crops, so that the bulk of the crop may be saved at the cost of that on the narrow strips or drainage furrows.

CHAPTER VIII

THE TILLAGE OF THE SOIL

THE tillage of the soil consists in breaking up the hard compact surface to a certain depth and converting it to a loose powdery mass, so as to enable the roots of crops to easily penetrate and spread in the soil. Tillage is the most important, difficult and labour-consuming operation in agriculture—a word which indeed means literally the tillage of the earth. Some 70% of the bullock labour in ordinary cultivation is taken up in the tillage operations alone. Success in crop raising will, to a large extent (other things being equal), depend on the thoroughness of this difficult operation. It is, as the parable says, the seed which falls on good ground that bringeth forth fruit and not that which falls on the wayside or among stones and thorns, and it is only by means of thorough tillage that the condition necessary for such bringing forth of fruit can be secured. Many objects are sought to be achieved by tillage, the combined result of which is a high state of productivity and these may now be gone into in some detail.

OBJECTS OF TILLAGE

The objects of tillage are the following :—

1. To break up the soil and to bring it into a suitable physical condition consisting of an aggregate of loose particles which will easily fall apart and crumble, into the kind described as 'friable' ;
2. to remove roots, stubble, weeds, seeds and other sprouting material like bulbs, stolons and roots, and produce a clean soil medium ;
3. to produce a condition favourable for ensuring an adequate supply of moisture for the use of the growing crop ;
4. to ensure ample aeration in the root range and bring about the changes, both chemical and bacterial, associated with aeration ;
5. to destroy insect pests and vermin which may harbour in the soil.

Each of these objects may now be dealt with in some detail.

1. *The Breaking up of the Soil.*—This is of course the most important and primary object and the others more or less follow it as a consequence. The untouched soil, which is being newly brought under cultivation or that of an aerable field which is to be prepared for a fresh crop after the previous crop, has its particles pressed close together and set fairly hard more or less according to the nature of the soil, *i.e.,* according as it is sandy, loamy, clayey or has an admixture of alkaline salts. The particles have to be pulled asunder so that

they will fall apart and run freely like a mass of very fine grains. Such grains of soil particles will be however only aggregates of still finer particles, and these aggregates are either small or large according to the fineness of tilth desired, which will depend much upon the nature of the crop to be grown. The separation is not to be carried beyond this degree, as otherwise it will be a case of grinding up or powdering the soil as in a mill. It is only in the state of comparatively loose aggregation that the fine roots of crop can easily traverse it, that water can easily percolate during a rain and later be held without clogging the air-spaces, and the necessary aeration be secured. The finest separation can be seen in the case of 'puddling' in rice fields and the coarsest separation in the case of the ordinary black cotton soils. In between the two extremes can be seen all grades. In the case of the peculiar so-called alkaline soils, the separation is abnormal; in the rains puddling and very fine division take place and in ordinary dry cultivation the tillage results in rather large and hard clods.

The reduction to this condition of tilth cannot be accomplished in a single operation but only by a succession of operations which are carried out at varying intervals and under favourable conditions of weather, after every one of which the succeeding ones become easier. At the first operation the soil is broken up into clods; these are large when the soil is not sufficiently moist or when it is inclined to be a heavy loam or small when the moisture is sufficient and the soil a good loam. In special cases the soil has to be broken up only into very large lumps in the hot weather so as to expose a considerable depth to the action of the sun and weather. This is the case in the cultivation of many garden crops and in the case of the black cotton soils for the destruction of deep-rooted weeds.

The breaking of the clods is the next operation. Under ideal conditions, the principal one of course being the moisture due to a rain in the interval, the clods naturally break to a considerable extent and fall apart, or at any rate can be easily knocked loose by the plough or other tillage tool. At every such opportunity the operation is repeated, until the soil is broken up and reduced into the fine condition required and to the depth desired. It is important that the correct stage of the moisture due to rain should be availed of; if the moisture is excessive, the grains will only run together and the tilth will be ruined, and the reverse process, *viz.*, puddling will take place.

This tillage in stages reduces the chances of weed infestation later on, because during the interval between the first and second ploughing many weeds seeds will sprout with the rains and these will be destroyed in the second ploughing. More weeds may come up after this ploughing also, to be destroyed at the next, so that it is a great advantage to carry out the operation in several stages. The young crop will thus have a better chance and the need for extensive weed control during the growth of the crop may be greatly reduced.

The preparatory tillage also rids the field of the old roots of the previous crop and weed roots, bulbs, stolons, etc., so as to clean up the soil in addition to reducing the weed infestation. The breaking of the clods results in the roots of stubble being shaken loose from the clods, and with the repeated ploughings these become free enough for easy removal. Roots and stolons are also torn asunder and brought up near the surface, to be gathered up and removed from the field. The more thorough such removal, the cleaner and more suitable the soil becomes for the crop. Such operations can be carried out by the plough itself but a great variety of other implements are used for the purpose which can do the work more efficiently and in less time.

2. *Soil Tillage and Soil Aeration.*—It is of the utmost importance that the soil mass should be so treated as to bring as large a surface as possible under the action of the atmosphere and for as long a period of time as may be possible during the preparatory tillage. The action is one of weathering which becomes necessary after the soil, especially the lower layers, has long remained very largely out of contact with sufficient air, owing to the compression, or the presence of much moisture, during which the products of root exudations have also accumulated. These conditions lead to a certain amount of "rawness" in the soil, which can be cured only by the abundant aeration and the heat of the sun's rays. During the repeated ploughings moreover considerable bacterial activity is induced which brings about the decomposition of plant residues, reducing the coarse cellulose material to a form in which it can easily mix with the soil in the shape of the so-called organic matter in the soil. The same activity will relate to the nitrifying organisms also, which may make use of both the plant residues and the bulky organic manures which may be applied. In well aerated soils both these go hand in hand simultaneously. Even after the crop is sown and during the period of growth there should be ample circulation of air in the soil as the plant roots need such a condition for healthy growth. The loose friable condition to which the soil is reduced by thorough tillage favours the entry and circulation of ample supplies of air in the soil.

The cultivation of rice presents a special case. Where the crop is to be grown entirely under puddle cultivation, the preparatory thorough tillage and aeration as for dry crops is not required and is even found positively injurious. The same is the case when rice is grown without rotation and always under puddle cultivation entirely. But when rice is grown partly as a dry crop (in the early stages) and partly as a flooded crop (in the later stages), or is grown throughout as a dry crop as in the case of dryland or upland paddy, then there is the same need for thorough aeration; indeed in this type of rice cultivation an exceedingly well-prepared seed-bed is considered even more necessary than in the case of other crops. Further, after the harvest of the crop of rice a very thorough breaking up and exposure of the clods to the sun followed by further plough-

ings is very necessary as the soil has remained submerged almost under anaerobic conditions during many months.

3. *Turning over and Mixing of the Soil.*—During tillage (with mouldboard or soil-inverting ploughs) the soil is turned over, the underside exposed to aeration and sunshine, the roots of weeds cut and upturned and the vegetation or remains thereof buried under. All these further help the above objects, while at the same time bringing about a more intimate mixture of the different parts of the tilled soil.

4. The preparatory tillage comprises also the incorporation into the soil, well and uniformly, of the bulky farm-yard or other manures like green manures. The same applies to the mixing of soil ameliorants like tank silt, sand or red earth or similar material, which are applied under some conditions, and which need to be mixed thoroughly with the soil.

5. *Breaking of 'Hard Pan'.*—Tillage often breaks up the hard layer or 'pan' below the level of the usual ploughing. This is necessary in many cases in order to facilitate the penetration of roots and the prevention of water-logging. A special attempt is made for this purpose with appropriate implements when the defect is very pronounced and calls for such action.

6. *Soil Tillage and Insect Pests.*—The breaking up of the soil brings to the surface the pupæ of several crop pests, which are thereby destroyed by the exposure or eaten up by birds. Nothing is a more common sight than the large number of crows and other birds which follow the plough when the field is being ploughed for the first time and which gorge themselves with the insect food of all kinds thus brought to the surface. Most of these pests pupate very near to the surface, at any rate within the ploughing depth, and are therefore destroyed in the operation. The ordinary *cumblihula* or hairy caterpillar pest (*Amsacta albistriga*) harbours itself in this way in myriads and the moths emerge in large numbers with the very first rain, before the plough can be put on the field. If a dry ploughing can be managed at all or some kind of deep cultivating too like a disc harrow set for deep working can be used instead, then much of the damage can be avoided by the partial destruction at least of this pest. Beetle grubs abound at these depths especially on the richer soils and thorough tillage will go a long way in reducing their damage later on. In the case of garden crops, fields are usually prepared by deep digging; in this case pests like the root-eating grubs of cutworms of many kinds are also destroyed. The white-ant pest is a very omnivorous and difficult pest to deal with, but even this can be destroyed to some extent by tillage or deep digging, except where the nests are very deep and the queen ants difficult to get at. Both by actual removal from the soil and by frequent disturbance of their harbouring places, tillage can very much reduce the chances of pest infestation and should be considered an important pest control measure.

7. *Tillage and Soil Moisture.*—Crop production is dependent in a large measure upon the provision of ample supplies of water for the requirements of the crop and in India may be said to be the most important and practically the limiting factor. As it is from the soil that plants have to obtain this all-important growth requirement, the soil has to contain throughout the crop season such quantity of water as may be necessary and sufficient for the crop at each particular stage. The moisture in the soil has also to be in such a form of association or contact with the soil that plants can readily take it up through their roots. Moreover even before the crop is sown, during the preparation of the soil, soil moisture is an important factor, as without its help tillage operations will be impossible and as in the presence of the correct degree of moisture tillage will be both easy and thorough.

The soil has to be put in such a condition firstly that it will take up as large a quantity as possible of the water, which the rainfall may supply. Over a hard unbroken surface of the ground much of the rainfall merely flows off and is lost to the soil; such loss may increase with the slope of the field. Leaving aside the question of bunding up the field in order to minimise the loss due to the slope, the loss can be prevented only by making the soil capable of receiving the water into it by opening it up for the entry of the water. With every ploughing, the soil lumps are made smaller and smaller, the rainfall penetrates the soil more easily and the surface area of the soil particles is largely increased, presenting a larger absorbing surface. The facility thus created for the largest amount of water to soak into the soil and be held in it in a condition suitable for absorption later on by the crop is a very important result of tillage operations.

Tillage operations subsequent to ploughings bring about conditions favourable firstly, for the rise of soil moisture by capillary force from the lower layers to the upper layers where the newly sown seeds will need it most, to enable them to sprout and the delicate rootlets to develop and secondly, for the preservation of the moisture so brought up within the soil itself by preventing or moderating loss by the drying effect of evaporation. The depth to which this force may act is regarded as very limited, but this somewhat moot point has been discussed already (*vide* Chapter on "Soil Moisture"). Within and during the period of preparatory tillage and the production of a proper seed-bed and later on of sowing, and until the intercultivation has to begin, its action is undoubted and one has to look to correct tillage to promote and help it on.

Harrowing After Sowing

After the sowing is finished, further operations of light tillage called harrowing, stir up the soil surface slightly, producing thereby the opposite effect, *viz.,* the prevention of the capillary rise of moisture. The coarse surface thus produced protects the soil moisture

below and conserves it for the use of the sprouting seeds somewhat like a protective covering or mulch. For the same reason the surface is given another light stirring in case there should be a shower of rain and the surface should become packed, the particles thereby brought close together and the capillary rise of water and the drying on the surface should be increased. Such stirring should of course be very light and done with care so as not to injure the sprouting seeds, although seed is usually sown much thicker than necessary in order to make provision for this contingency.

INTERCULTIVATION OR TILLAGE

At a later stage in the growth of the crop comes intercultivation. The object of such tillage is twofold, *viz.*, for the purpose of conserving the moisture supply in the soil, so that it may be available as fully as possible for the use of the crop, and for the destruction and removal of weeds, which at the same time conserves the moisture for the use of the crop. Such tillage takes more than one form, but all of them are generally of the light surface stirring type and are not by any means deep. In the case of some row crops like jowar, however a light ploughing is given between the rows of the young crop which has for its object the collecting of the rain-water close to the roots of the crop, by making a shallow furrow adjoining each row on either side. In all other cases the space between the rows is stirred lightly with various kinds of intercultivating tools. Both "Intercultivation" and "Weed Control" are however dealt with in detail separately.

Soil tillage thus consists of the series of the main preparatory operations which result in a suitable seed-bed, (1) by breaking up of the soil mass and the gradual reduction of the mass into an aggregate of fine grains; (2) the general cleaning up by the removal of stubble, crop and weed roots; (3) the reduction of the chances for the multiplication of weeds; (4) reduction of the infestation or outbreak of insect pests; (5) the creation of the condition necessary for the reception of the rain-water into the soil; and later (6) of conserving it for the use of the crop; and lastly (7) of incorporating bulky manures and soil ameliorants uniformly in the soil. Next to the preparatory tillage comes the light harrowing to restore the soil mulch in the field after the crop is sown and later on the interculturing operations. The tillage may be said to close with these operations, except in special cases where if conditions are favourable the somewhat difficult operation of a post-harvest ploughing is attempted.

METHODS OF SOIL TILLAGE AND TILLAGE IMPLEMENTS

THE tillage of the soil consists, as already explained, of two kinds of operations, *viz.*, (1) the elaborate and difficult operation of preparing the soil for sowing, which really comprises a series of operations, and (2) the light operation of intercultivation, which is taken up later. The farmer is by far the most important and fundamental operation and one to which the name tillage is sometimes confined.

The preparatory tillage may be carried out (*a*) by the manual labour of digging the ground with hand tools, (*b*) by ploughing with bullocks or other draft animals, and (*c*) by mechanical power.

A. Digging and Manual Power Implements

The digging of the field is generally confined to small-scale garden cultivation and as an agricultural or field operation is of minor importance, except in countries like China and Japan where agriculture itself is of the garden type and bullock power is almost entirely dispensed with, and manual power is used instead. It is naturally very much slower than work by bullock power but like all manual operations in agriculture it is more thorough. Digging is confined to the initial breaking up of the soil, which is thrown up in very large clods and is often left in that condition purposely with the object of thoroughly aerating the full depth of the soil dug up and the surface of the clods. During the digging, the clods are generally turned over, so that much of the top layer or surface goes to the bottom and *vice versa,* somewhat as in the case of ploughing by a mouldboard plough which inverts the ploughed soil.

Various digging tools are in use in different parts of the country which differ somewhat in the quality of the work turned out and the ease of operation. Crowbars, mattocks and the digging forks and spades are tools which enable the workmen to do the work in a standing posture. The crowbar and the mattock are pushed into the soil and the clods are levered up, the crowbar being used for hard soils and the mattock for easy working loams. The digging fork, spade and shovel are used by pushing the working end into the soil with the foot pressing it down and the weight of the body helping. In both these cases greater depth and efficiency are secured if the implements are driven down as nearly vertically as possible; the greater the slant the less is the depth.

The '*mammoties*' and '*guddalis*' are tools which are used for comparatively easy working soils, they have to be used by men in a stooping posture, and are suitable for the customary Indian style of working. The '*mammoti*' is a very efficient tool, large slices of the soil about the width of the blade (some 6" to 10") are cut out and thrown over or inverted. The depth and efficiency are greater in the

type in which the blade is attached at right angles to the handle; with the other types in which the blade is attached at a narrower angle to the handle (and are sometimes described as "goose neck" style) the depth is less and when the angle is narrow, the type becomes simply a shovel for moving the loose earth or working in moist or very easy working soils. The *'guddali'* is a digging tool in which the working end is a flattish bar attached much like a very slanting *'mammoti'* blade; it cuts only a very narrow width and for the same amount of force, it can dig a little deeper and with greater ease, as the digging end is sharp-pointed. It is the favourite digging tool in many parts of Mysore. All these three types of tools draw the dug soil towards the worker who has therefore to walk over the clods or dug up soil as the work progresses. In the former type the reverse is the case and the worker walks on level undug ground.

Work with all these manual power tools is slow and very variable, depending on the skill and strength of the worker, and of course, with the nature and condition of the soil. On the black cotton soil and in the hot weather, digging with the crowbar may require about 40 men per acre, while with *mammoties* and on moist soil 12 to 16 men may cover an acre per day. With a digging fork or shovel (on British farms) about 15 or 16 men can dig an acre of garden soil.

The next operation, *viz.,* the crushing or breaking of the clods is carried out by a further digging with the *'guddali'* itself or by means of wooden mallets where the soil is clayey and does not fall apart by the mere digging itself and more effort is needed for the purpose. The mallet is either long-handled, which enables the worker to use it with very little stooping or short-handled and suitable for using in a sitting posture, the usual one adopted in this country.

In the work of gathering the stubble, weeds and roots, hardly any tool is used, but occasionally small rakes both of wood and of iron with short handles for working in a sitting posture or long handles for use in a standing posture are used; the latter is the better of the two and deserves to be largely adopted.

Interculturing tools for manual labour comprise a large variety of models, mostly weeding hooks, some with a pointed end, others with a wide bladed end, some with only one point, others with many prongs, etc. The farm which is a miniature *'guddali'* does both light digging and removes weeds by uprooting them; the bladed type has a scraping effect, the blade being pushed along the surface forward and under the weeds, thus scraping off the weeds and some soil along with them. Both types do efficient work and can hardly be improved upon.

B. Ploughs and Other Bullock-drawn Implements

Ploughs

The plough is the basic implement in agriculture just as its work, *viz.,* tillage, is the basic operation. The plough does on a field

scale what the manual power implements like the digging tools described above do on a small garden scale, but more quickly and in a less laborious manner. The plough is the most ancient and important implement of civilised mankind, typifying the epoch when mankind ceased to lead a nomadic and pastoral life and changed over gradually to agriculture and a settled life. The plough probably is the first attempt by man to devise an implement which will utilise animal power in tilling the soil, dispense with the slow drudgery of manual labour and make large-scale work possible.

It is a most remarkable circumstance that notwithstanding its ancient and hoary origin, the implement has essentially retained its primitive type and design in all but the most advanced countries and that even in these latter countries it remained unchanged until a hundred or hundred and fifty years ago. Jethro Tull, the famous pioneer in agricultural improvement in England in the 18th century in his book "New Horse Ploughing" published in 1731, made the following indictment against human talent in this respect:—" 'Tis strange that no Author should have written of the Fabric of Ploughs! Men of the greatest Learning have spent their Time in contriving Instruments to measure the immense Distances of the Stars and in finding out the Dimensions and even Weight of the Planets; they think it more eligible to study the Art of ploughing the Sea with Ships than tilling the land with ploughs; they bestow the utmost of their skill, learnedly, to prevent the natural Use of all the Elements of Destruction of their own Species by the bloody Art of War. Some waste their whole lives in studying how to arm Death with new Engines of Horror and inventing an infinite variety of slaughter; but think it beneath Men of Learning (who only are capable of doing it) to employ their learned Labours in the Invention of new (or even improving the old) instruments for increasing of Bread."

The Indian Plough

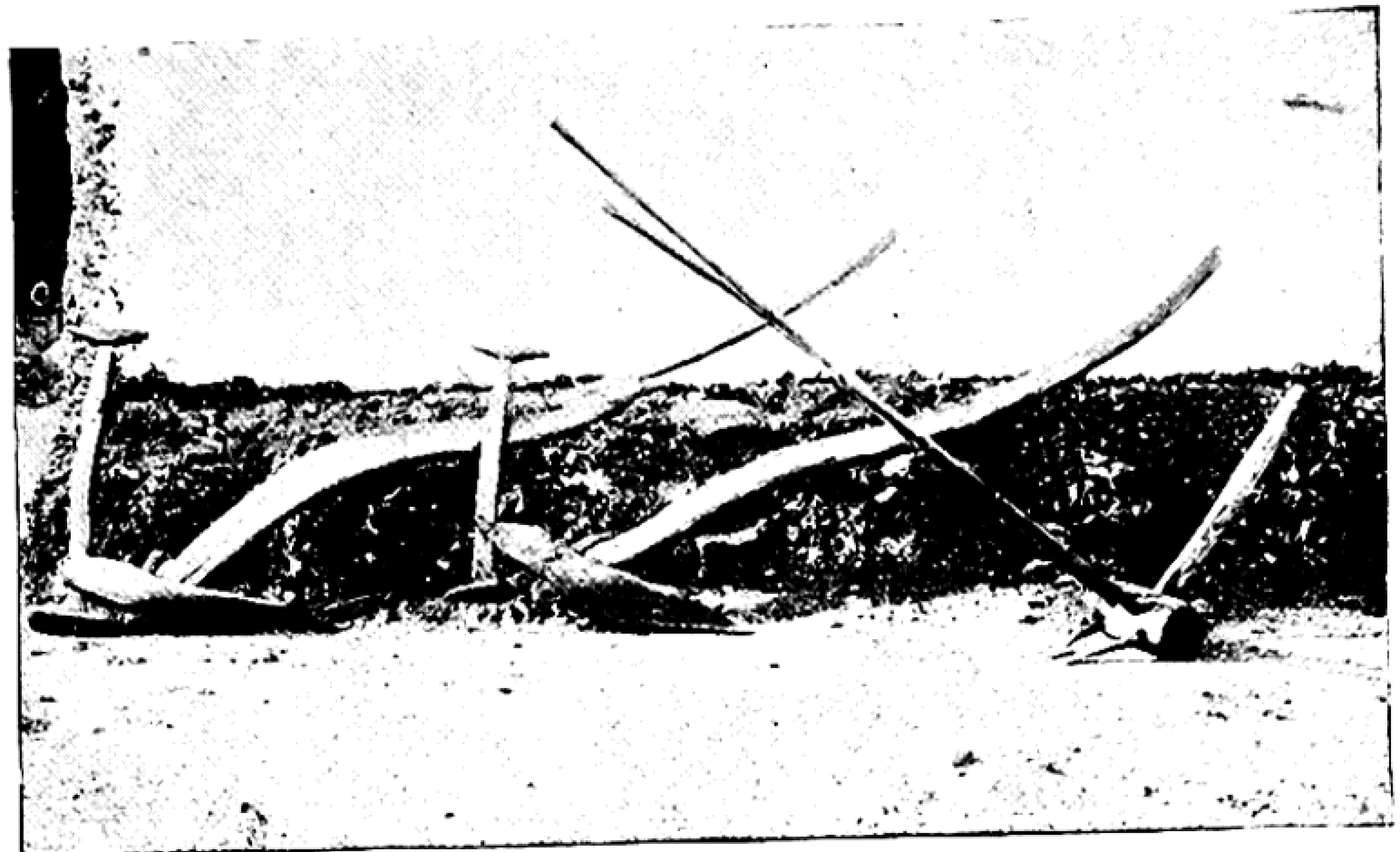
The ploughs used in India are certainly crude and are very primitive in construction, and appearance. They comprise a rough wedge of wood with an iron point nailed to the end as the main or working part which does the breaking of the soil, with a short vertical handle and a beam attached by the crudest piece of joinery, both of them also made of wood. They are all-wood in structure except the iron point which helps the penetration; they are very simple and hardly need a carpenter's help worth mentioning. The wood for all the parts is locally available and the village blacksmith provides the iron point and the staples which fasten this to the wedge. It is a cheap, simple home-made article. The wooden wedge comes from some special hard wood timber, the *jali* (*Acacia arabica*) being a favourite. The handles and beam are just rough natural wood, a suitable length of branch for the former and a wooden pole or bamboo for the latter. All ploughs are only single-handled, about 3′ in height reaching to about the waist of the ploughman, who holds and

often presses it down with the left hand, while with the right he drives and guides the bullocks. The beam (or hitch) is also a single piece, to which at the forward end the yoke is tied across; the bullocks are very close to the ploughman who does in fact reach them easily with his hands. When tied up ready for work it is fairly rigid and steady. The yoke is not connected by any rope or chain to the end of the beam, which will make the arrangement less rigid and the guiding of the bullocks less easy. Where however more than one pair of bullocks has to be used, as in the case of the heavy ploughs, the use of ropes becomes indispensable in the case of the pairs leading in front of the first pair, which is nearest to the ploughman.

How the Plough Works.—The nature of the ploughing or breaking up of the soil, performed by this type of ploughs, consists in the opening of a furrow-shaped somewhat like a V, the earth being thrown upon both sides of the lip of the furrow and much of it also falling back into the furrow. The depth of the furrow and its width may vary according to the size and set up of the working part or plough bottom, but ordinarily the depth does not exceed 4" and the width above 6" at the top which is the widest part of the furrow.

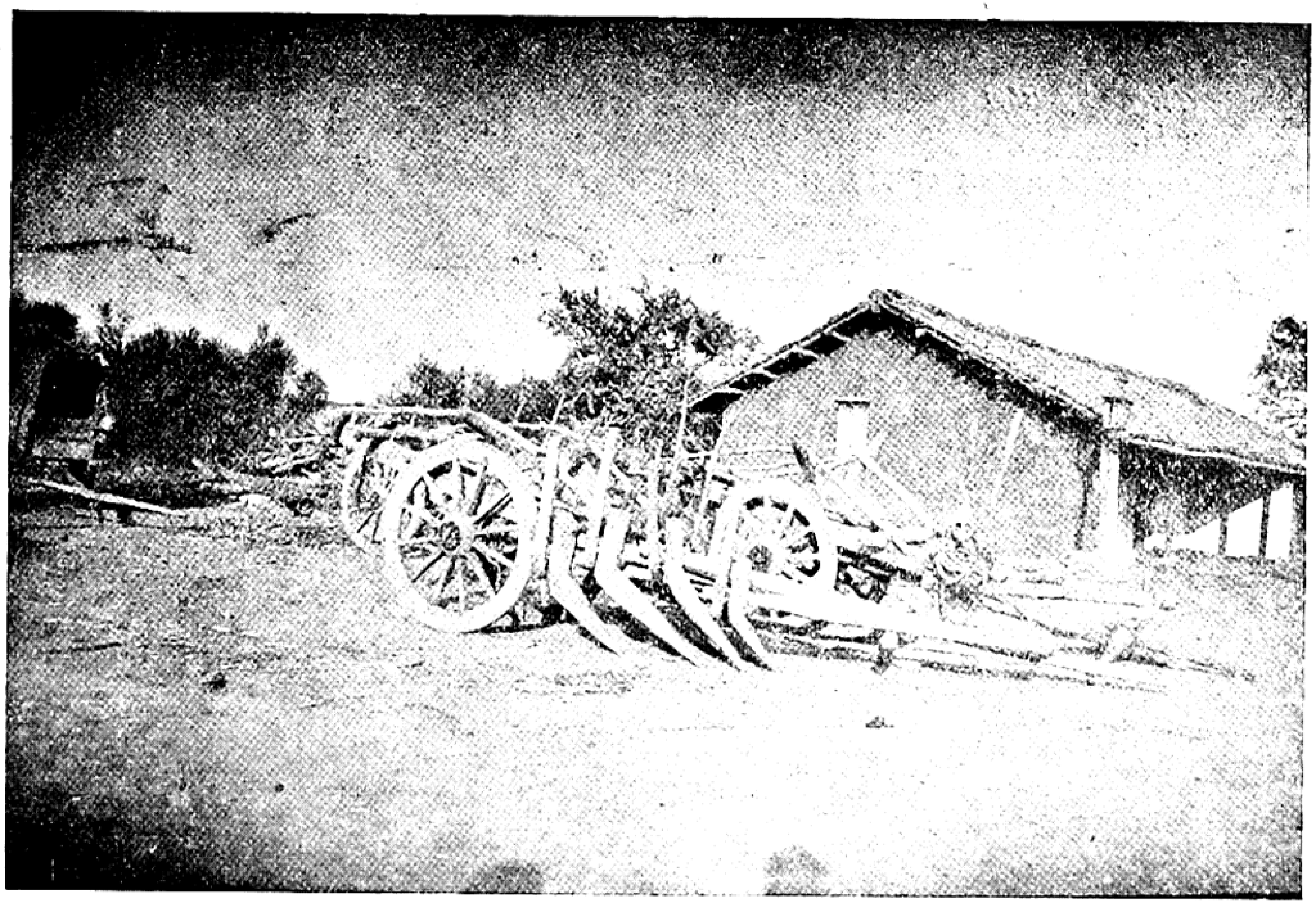
The plough bottom or working part of the plough consists, as already stated, of a heavy wedge of wood. The wedge is V-shaped in cross-section and the furrow ploughed is also therefore V-shaped. The wedge is also V-shaped along the length, pointed in front and wide at the rear. The angle of the V in cross-section may vary and likewise the width of the wedge at the rear. The wedge is either one straight piece of timber or has a bend like an elbow at the rear; the angle which the elbow makes with the wedge also varies in different types. In these elbow types the handle is attached to this elbow, which is generally of sufficient length for attaching the beam also. Where the elbow is absent then both handle and beam are attached to the rear of the wedge or plough bottom itself. In this type the wedge travels in the soil almost flat, cleaving it and making a furrow as deep as the vertical thickness of the wedge and as wide as the rear or heel of the wedge. In the types which have an elbow, the full length of the wedge does not move in the furrow and lying flat as in the former, but travels somewhat slantingly, and up to a depth which in this type can be varied slightly as desired.

Adjustments.—The depth of the ploughing is capable of some adjustment, by the simple process of raising or lowering the beam, *i.e.*, reducing or widening the angle which the beam makes with the ground; this is managed by driving a thin wedge either above or below the joint which unites the beam to the handle or the elbow of the plough bottom, the former reducing the angle and the latter widening the angle. With the same pair of bullocks, the adjustment for depth is also made even more simple by tying the bullocks nearer or farther to the ploughman, the latter making the work deeper and the former less deep.



Country Ploughs of the shallow type referred to in the text—Also an interculturing hoe.

Mys. Agr. Dept.



The heavy type of wooden ploughs, for deep ploughing on black cotton soils. Note also the carts fitted with special frames for widening their base.

Photo by Author

Different Sizes in Ploughs.—In addition to the somewhat minor differences due to the shape of the plough bottom and the method of attachment of the handle and beam, ploughs differ according to the size. Thus in the Mysore State five types can be seen : (1) The paddy soil plough, common where puddle cultivation is the rule. This is very light, the plough bottom is small, just suited to ploughing a few inches in the soft puddle, so light indeed that some four or five can be carried on one's shoulders. (2) The general purpose plough, which is in use for all dryland ploughing and is much larger than the first. (3) A heavier type than the second, which is used for deeper ploughing and on the black cotton soil. (4) A very heavy plough used for summer ploughing on the black cotton soil almost as a substitute for digging and which requires some four or five pairs of bullocks to draw. (5) A special type of plough : A plough of special interest is the light plough used in the 'malnads' which is quite different in the shape of the plough-bottom ; this is in the shape of an inverted V, the bottom being hollowed out to this shape. The work of this plough resembles that of a miniature ridging plough ; it is also better fashioned, the plough bottom, beam and handle all being shaped and turned out by carpenters. The ploughed soil falls on both sides of the plough and the furrow bottom is not covered up. It may be considered as the nearest approach in this respect to the mouldboard plough, though of the ridging type.

Work of the Plough.—Barring this important exception the work of all the local Indian ploughs is of one type, *viz.,* the furrow is V-shaped and there is no inversion of the soil. On account of this shape of the furrow, an unploughed strip is always left between one furrow and the next, which is very narrow if the ploughing is careful and the furrows are ploughed very close to each other but is unavoidable even in the best ploughing. Ordinarily this unploughed strip is considerable and is almost as wide as the furrow itself. When the field is cross-ploughed little squares of unploughed ground still remain which have to be tackled by one or more further ploughings. In order that the whole surface may be ploughed up several ploughings are thus necessary. In the mouldboard plough the very first ploughing itself cuts up the whole surface and as far as ploughing goes the work is complete. This is a very great saving in time and when it is remembered that one has to wait for a good rain before ploughing can be resumed, this great advantage of a mouldboard plough can be appreciated ; this contrast moreover clearly brings out the nature of the work peculiar to the indigenous ploughs.

The contrast consists both in the saving in the time of ploughing and in the fact that the local ploughs do not invert the soil. The action is one of merely stirring the soil, more or less *in situ* shallow or deep. Taking only the inversion of the ploughed sod as a special feature for consideration, opinions differ as to the need for such inversion or advantage in Indian soils, as a general practice,

the main reason being the risk of bringing up raw or at least a less fertile soil to the top which is likely to be prejudicial to the crop. As the depth of ordinary ploughing seldom exceeds 4", this consideration does not weigh at all, and as a matter of fact many instances can be quoted in which the mouldboard plough brings about an increase in yield. The main practical drawback of all local ploughs as far as work is concerned is their slowness or imperfect nature, which is due to the shape of the furrow they cut, and it is on this account that there is need for their replacement by mouldboard ploughs.

The Improved or Mouldboard Plough

This name is given to the iron ploughs of the mouldboard type, which have been imported from abroad and which are now made in large numbers with suitable modifications in this country itself. These ploughs are made entirely of iron or steel or partly of metal and partly of wood (especially the local modifications) and are of several types and sizes.

They consist essentially of the following parts: (1) the plough bottom which comprises the 'frog', to which are bolted the share, mouldboard and landside; (2) the beam to which are attached the hitch or hake and quadrant; (3) the standard which connects the plough bottom to the beam; (4) the handles with the necessary bracing. There may be found in addition a coulter, a wheel, or two wheels (land and furrow), etc., in various types but those imported into India or adapted locally do not possess these parts and are made as simple as possible. The main part is the plough bottom, which is really the working part.

To the frog (1) are bolted the share (2), the mouldboard (3), the landside (4), and the standard (5). (Reference is to numbers in the accompanying illustrations.) The share is the part which cuts the furrow slice, this travels up the mouldboard and in this journey becomes slowly inverted, due to the peculiar shape of the mouldboard, and is thrown to one side. The landside keeps the earth from the unploughed side from falling into the furrow. All the furrow slices are thrown uniformly on one side of the plough, *viz.*, the right-hand side in this particular type. The furrow is L-shaped and the furrow slice is rectangular in section generally and this particular shape of the furrow permits of complete ploughing without leaving unploughed ridges as is the case in a V-shaped furrow. In this respect it resembles the digging work of a *mammotie* or spade.

Adjustments.—Both width and depth are adjustable by the attachment of the chain or rope to the hake and quadrant; for increasing the depth the hitch is at the hole at the top and for reducing the depth the attachment is at the bottom or lower hole. Uniformity of depth can be secured only when the plough moves level on the floor of the furrow; sometimes the ploughman presses at the handle, and this has the effect of tilting the point of the

plough slightly up and therefore of taking less depth. Sometimes on the other hand he may lift the handle slightly, when the point of the plough will tend to work into the ground deeper; both these may be required occasionally to tackle difficult spots here and there. If necessary as in the case of the local plough itself, depth may be increased or reduced by hitching the bullocks a little more forward or backward respectively.

The width of the furrow which the plough is set to plough is given by the distance from the point of the share (or the landside) to the tip of its wing, as the depth is likewise the distance from the sole of the plough to the top of the mouldboard where it begins to turn away from the standard (also called the 'neck' of the plough). For adjusting the width of the furrow the holes in the quadrant are made use of; for widening the furrow the chain is attached to the hole farthest away from the unploughed side, *i.e.*, to the right in this plough. If the furrow has to be narrowed then the chain is attached to the opposite side, *i.e.*, to the left in this plough. The change in the attachment has the effect of making the plough bottom travel slightly to the left or right taking more or less land. Normally the width which a plough is intended to plough is about twice (or a little more) than the depth. A well adjusted mouldboard plough is expected to move evenly once it has begun to plough and moves on an even keel, so to speak; but this is not possible and the plough has a tendency on account of the nature of the ground to work out of the ground or to move into the ploughed ground and thus not to take the full depth or the full width. In order to correct this tendency the plough is given a "suction", that is to say, the surface or sole from the point of the share is not level with the heel, so that a straight edge put along the sole from the heel to the tip of the share will show a gap between it and the sole, which is usually about $\frac{1}{8}''$. Similarly on the landside also there is a slight gap or curvature amounting to the same $\frac{1}{8}''$. This space which is called the "suction" enables the plough to 'suck' or hold on to the bottom and the side of the plough bottom.

Many additional parts can be seen in different models of the improved mouldboard ploughs, such as wheels, galleys, coulters and so on, but in the Indian models these are dispensed with for the sake of simplicity. The mouldboard is an important and distinctive part of these improved ploughs. It has a peculiar shape, somewhat resembling a propeller blade or a twisted throng, as the result of which the soil inverting action takes place; the furrow slice has to move up this mouldboard and then to turn over. The mouldboard may be short and rather high or it may be long and somewhat narrow or intermediate between the two shapes. The first type sharply bends the furrow slice and therefore crushes and breaks it, while in the second the furrow slice is completely turned over gradually and is broken to a less extent. Coarse loamy soils are suited to the first

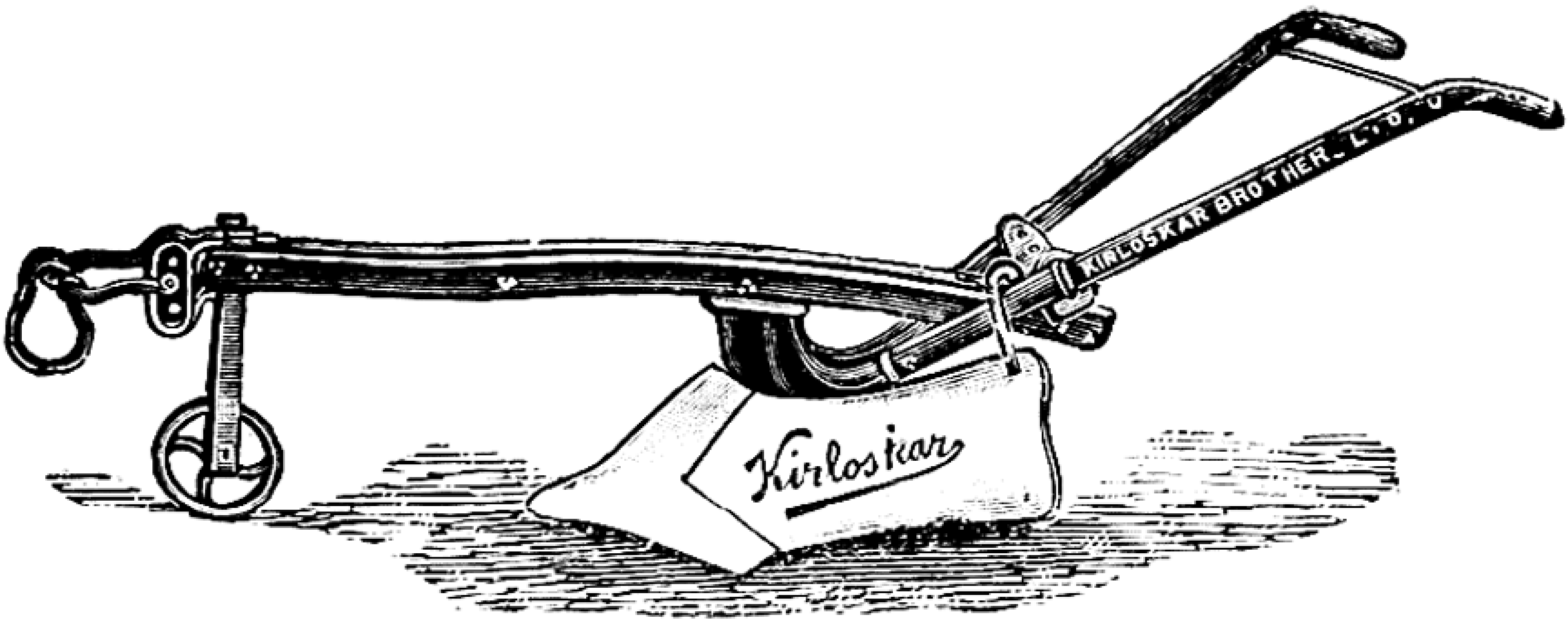
type and clayey and fine soils to the second type. The intermediate one is a kind of general purpose plough.

The surface of the mouldboard is not only very hard wearing but is also smooth and polished, so that the furrow slice can travel over it with the minimum of friction and none of the soil may stick to it. If the surface is rough, then the soil of the furrow slice will stick and the mouldboard will not 'scour' properly. As a matter of fact, the work of the mouldboard is a considerable addition to the draft required and its condition has therefore to be kept such that no needless addition to the draft is involved by a coarse or rough surface.

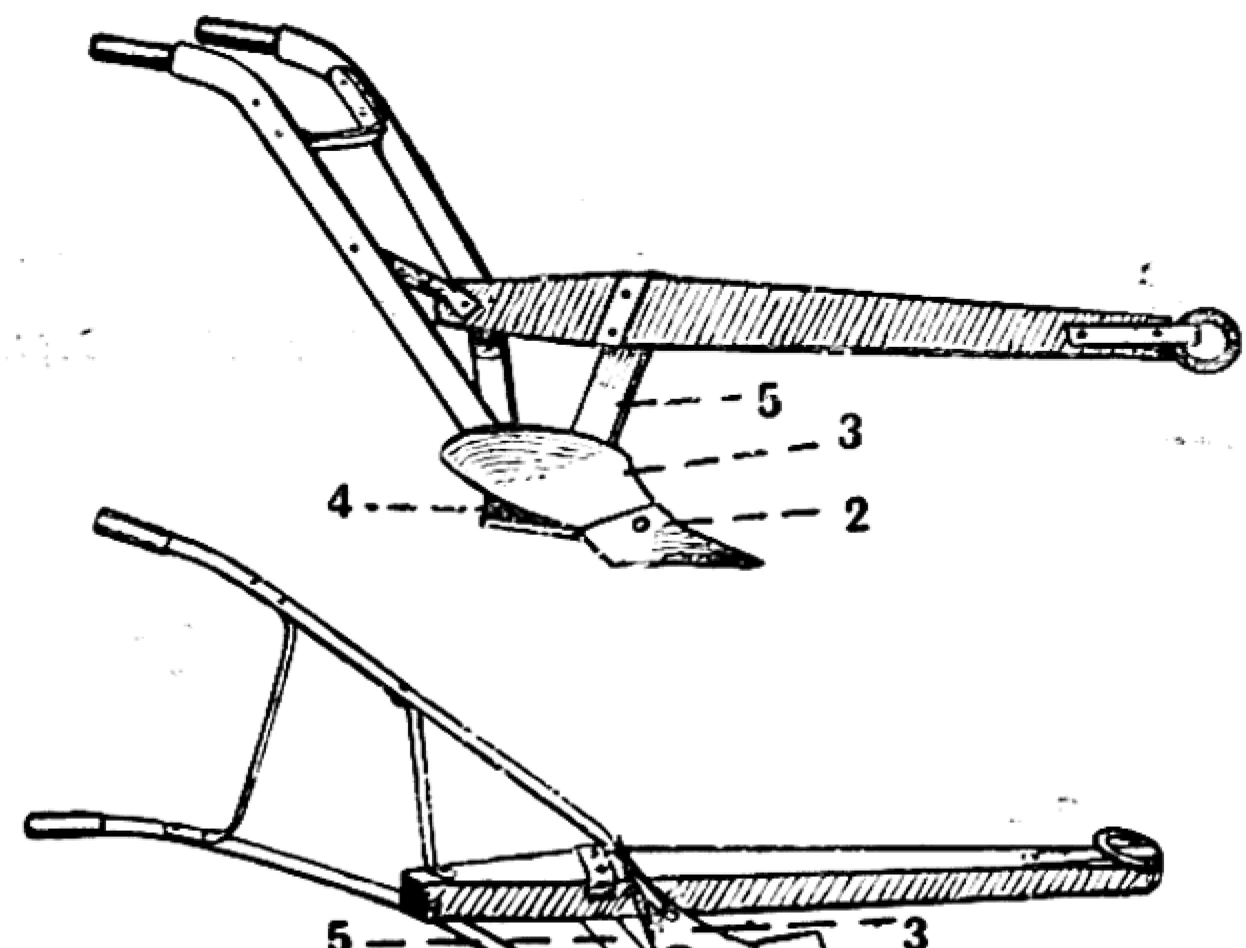
'Turnwrest' or 'One-Way' Ploughs

In the ploughs described above both share and mouldboard are attached to one side of the frog or foundation, usually the right-hand side and the plough always throws the furrow slice on that side. Left-hand ploughs in which the frog is adapted to carry the share and mouldboard on the left-hand side are also made but are rather exceptional. In both types the plough can obviously be used only as a right-hand or as a left-hand plough. There is however another type in which the construction is such that it is possible to use it either as a right-hand or as a left-hand plough as desired. These are called "one-way" or "turnwrest" or "hill-side" ploughs. They are either composite types, consisting of two separate ploughs which are so mounted that one works in the soil and the other is lifted out and remains idle or more commonly the share and mouldboard are so shaped and mounted that they can be swung to right or left in the plough foundation and fastened in that position. The Kirloskar ploughs now being manufactured and used in large numbers in India are mostly of this type and the type has become quite common and important.

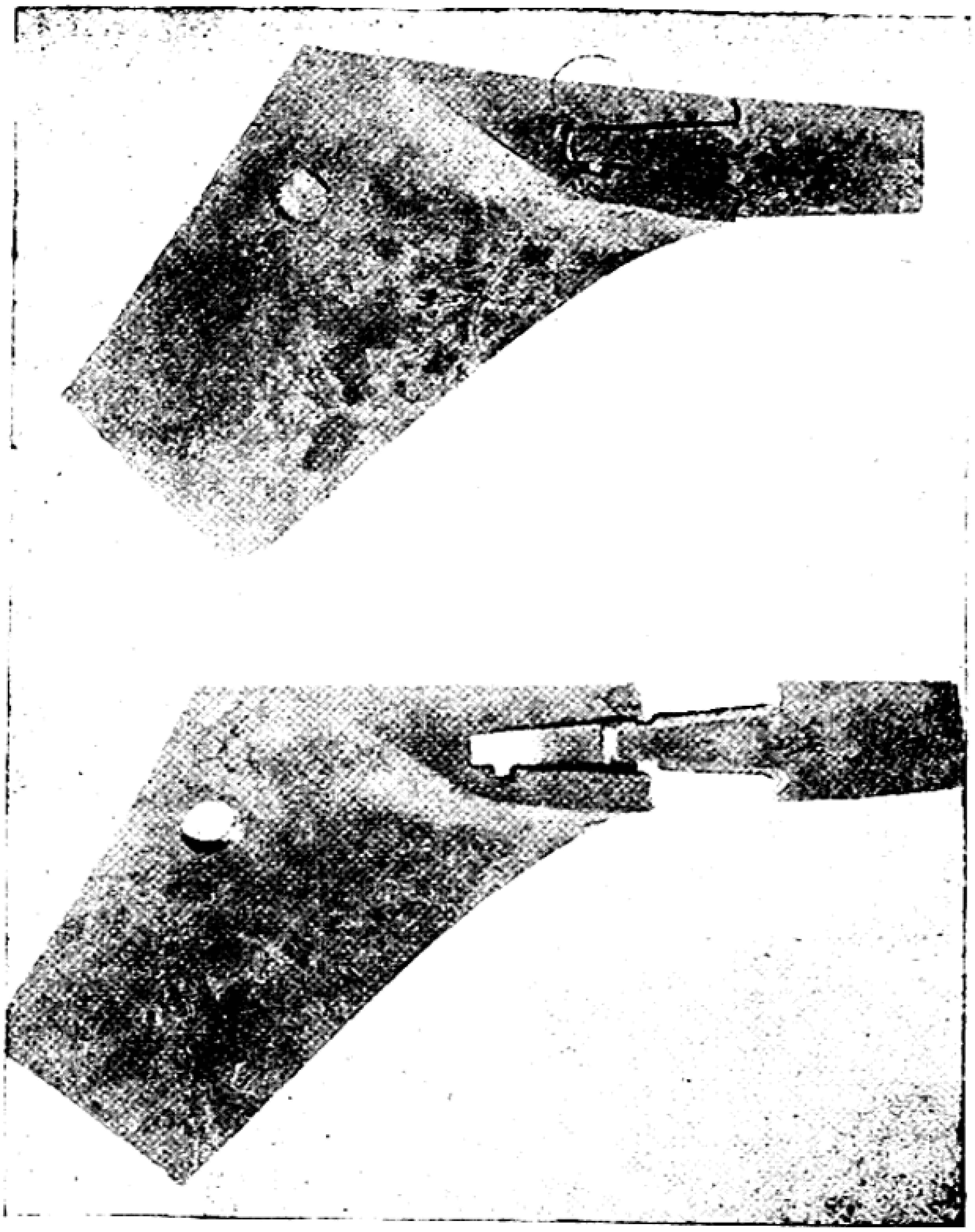
Adaptations to Indian Requirements.—Before leaving the subject of the parts of improved ploughs, some adaptations or features suited to Indian requirements and found desirable may be considered briefly. In view of the small bullocks used for ploughing, it becomes necessary to reduce the weight of the plough as much as possible without sacrificing its special character and for this purpose it is desirable to reduce the size of the plough, to dispense with all non-essential parts and to cut down the use of cast iron parts which add to the weight of the plough and use only soft centre steel for both share and mouldboard. A six-inch or even five-inch share plough bottom will be enough (with the other parts in proportion in any general purpose plough). The frog and standard which have to be of cast iron must be made as small as possible and the standard made only of flat iron (as in the case of the K.M. plough) both of which will bring down the weight of the plough. The short beam intended to have a chain attachment is not always found necessary. In many cases a single long wooden beam as in the case of the local plough



Turnwrest plough, a popular mode manufactured by Messrs. Kirloskar Bros.
By Courtesy of the Company

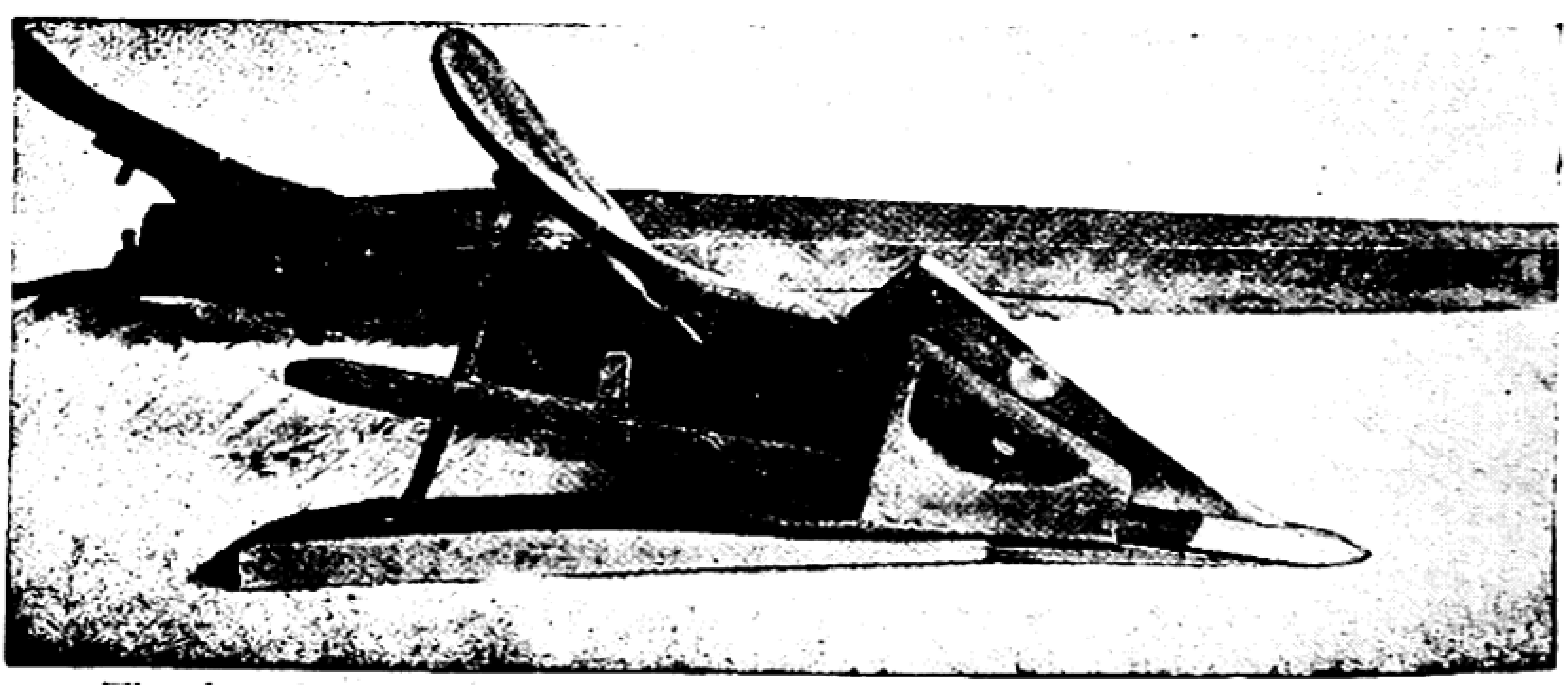


The Kolar Mission Plough, a very simple type of mould board plough, popular in Mysore—the main parts are indicated thus: 1. The frog or foundation. 2. Share. 3. Mould board. 4. Landside. 5. Standard.



Slip point shares, referred to in the text, showing the method of attachment of the point.

Mys. Agr. Dept.



The bar-share plough, view of the under-side showing how the bar fits into and is held in position in the "frog".

Mys. Agr. Dept.

can be substituted; as a matter of fact this alteration is made by the local farmers themselves. The handles of which two are provided in the improved ploughs may also be changed and only one provided for suitable attachment. Both these features will make the type approximate to the indigenous plough in this respect and will suit the peculiar habit of the Indian ploughman. It is easy to provide adjustment of depth, by having three holes in the top of the standard which may in addition have a slight curve like a quadrant for the purpose.

In Mysore the two handle plough has become popular and farmers have become quite used to it; but the hitching of the bullocks is peculiar and the arrangement gives it more rigidity than the chain hitch and also brings the bullocks nearer to the ploughman. Moreover pressure is continuously put on the left handle as this is the only handle held, the other being free to manage the bullocks. This makes the wear of the plough bottom more on the left side, which ceases to be level after some time. All this only demonstrates that the preference is for a single handle and long beam, without a chain attachment, in order to have the bullocks close to the ploughman.

The share and the mouldboard have to be of first class material, so that they may be hard wearing, light and capable of 'scouring' neatly, *i.e.*, throwing off the soil without any of it sticking to the surface and needing to be scraped every now and then and adding to the draft of the plough.

'Slip-point' Share and 'Bar-point' Share.—The share wears out very soon and has to be replaced by a new one. This is a very expensive item, as shares do not last more than for five acres of first ploughing. At it is the point of the share which wears soonest necessitating the discarding of the entire share, the difficulty has been attempted to be got over by making the point as a separate and detachable piece, so that as soon as one point wears out another point may be fitted, instead of throwing away a whole share. Share replacement is certainly much cheapened thereby, but these two-piece shares—called "slip-point shares"—have to be made of cast iron and are liable to break. In a second type, the share-point is furnished by a steel bar fitted to the bottom of the plough, the sharp end fitting into a slot at the end of the share. When the pointed end wears, the bar can be pushed forward through the slot and fixed in position and this can be repeated as often as may be necessary until the bar becomes too short. In this type also—called the "bar-point share"—not only the share but the body of the plough also has to be made of cast iron, which makes the plough rather heavy in addition to its liability to break. The one-piece steel share is therefore preferred in spite of its cost, and improvement should be made in the direction of cheapening it, probably by local manufacture. A steel share has the

further advantage that when its end becomes worn a new piece can be welded and the life of the share prolonged.

Methods of Ploughing with the Mouldboard Plough.—In actual ploughing, whether with the local ploughs or the mouldboard ploughs it should be remembered that the ploughing should be along the length of the field and that this length should be as great as can be secured. If two small fields adjoin and be on the same level, it will be an advantage to consider them as one for this purpose and increase the length thereby, lifting the plough if necessary to clear the separating bund. The greater the length, the less will be the time lost in turning. Some of the longest furrows can be seen in the black cotton soil tracts, where the length may go up one furlong. This ensures great economy. Since however the plough has to be turned at each end of the furrow, the width of the turning is kept as low as possible. The field is therefore ploughed in long narrow strips, one strip after another, until the whole field is ploughed.

In the case of the mouldboard ploughs the ploughing can be done in one of two ways, *viz.,* by 'gathering' or by 'splitting'. In the method of ploughing by 'gathering' a central furrow is opened in the narrow strip marked out, the plough is turned to the right (the mouldboard side) and an adjoining furrow is ploughed; the two furrow slices being thus made to lie closely pressed against each other, forming a kind of ridge. At the end of this furrow, the plough is again turned to the right and the third furrow, is ploughed alongside the first furrow, at the end of which the plough is again turned to the right and the fourth furrow is ploughed, which will lie alongside the second furrow. This is repeated furrow after furrow until the whole strip is finished. This means that the ploughing is round and round a central furrow where it is begun, and is finished at the sides. This leaves a sort of ridge or crown along the central furrow, where the ploughing was begun.

In the second method called 'splitting', the ploughing is begun at the right-hand end of the strip and the first furrow ploughed; at the end of this furrow the plough is turned to the left, taken along to the opposite side of the strip along which the second furrow is ploughed; the plough is now turned again to the left and taken to the end where the ploughing was begun and the third furrow is ploughed alongside the first after which the plough is turned again to the left and taken to the opposite end where the fourth furrow is ploughed alongside the second; this is repeated until the strip is finished. The finishing takes place in the middle of the strip, where a double furrow is left with two furrow slices thrown on opposite sides and away from each other, thus leaving a double furrow in the middle where these two last furrrows meet.

Ploughing may be done by either method but in British practice the field is 'split' and 'gathered' in alternate strips, the strips being usually about 11 yards wide; the surface of the ploughed field having crowns or ridges of the gathered strip alternating with the double

furrows of the split strip or a sort of wavy outline. This method is adopted in order to help surface drainage and in the belief that a larger surface area is secured, and greater exposure to sunshine. Indian ploughmen do not like this uneven surface produced by wide furrows and crests of the mouldboard plough, and always try to obliterate them and restore the level surface, keeping only very shallow double furrows between the strips.

Work by the 'Turnwrest' or 'Hill-side' Plough.—With the turnwrest plough it is possible to avoid this large turning round and to plough furrow after furrow with all the furrow slices turned in the same direction. This is managed by working the plough as a left-handed mouldboard plough for the first furrow, turning around at the end, altering the plough to a right-hand mouldboard plough and ploughing the second furrow alongside the first; the plough is changed now back again into a left-hand mouldboard plough at the end of this furrow and the third furrow is ploughed alongside the second and so on. The plough becomes a left-hand mouldboard and a right-hand mouldboard plough alternately as each furrow is ploughed. The arrangement for such changing is very easy and can be done in a trice. The ploughing thus leaves no prominent ridges and double furrows and the field is level, the surface being broken only by the regular series of the crowns of the furrow slices. The plough has also another advantageous feature, *viz.*, that the same bullock is not obliged to walk over the clods of the ploughed surface but each bullock gets this track alternately and the discomfort of walking on the clods becomes evenly divided between the two bullocks of the pair. On the black cotton soils especially this is a much appreciated feature, as the walking on the large rough clods is a strain. In hill-side ploughing, this type of plough enables ploughing with all the furrow slices thrown facing only one way, *viz.*, the bottom of the hill.

Disc Ploughs

The ploughs considered so far do the work of cutting the sod either by the familiar wooden wedge (reinforced with iron) of the indigenous wooden ploughs of different sizes or by the steel share and mouldboard of the improved ploughs. There are other types in which the cutting is done in a different way altogether. These are the Disc ploughs and the Rotary ploughs. In the Disc plough, the soil cutting tool is a large thin sharp-edged disc of hard steel, which is so mounted that it revolves in a plane slightly inclined to the vertical, cutting and throwing up the soil as the plough moves along. The disc is shaped like a large but very shallow saucer and revolves round a central axis. The plane in which it moves is not exactly vertical but slightly at an angle from the vertical, so that as it revolves it cuts off a slice of the soil similar to a furrow slice, whose thickness will depend upon the angle at which the disc leans from the vertical, and throws it to one side with the

slice partially turned over and much more crushed and pulverised than in a mouldboard plough. Disc ploughs are designed for riding ploughs and tractor ploughs and not for walking ploughs, as in the case of the mouldboard ploughs which are designed and suited for all kinds. For the same width and depth of furrow the disc ploughs are claimed to involve less draft.

ROTARY PLOUGHS

The Rotary plough or "Roto-tiller" is a comparatively recent type although the original design is said to be fairly old. The digging or cutting part of the implement is a kind of very narrow but very strong pointed blade somewhat like a cultivator, a number of which are mounted radially like the spokes of a wheel on a rotating shaft, which revolves as the plough moves along and brings one blade after another to bear into and cut the soil. The action resembles a quick succession of strokes by a cultivator or narrow spade, delivered as the machine moves along and leaves the soil in the track completely tilled, broken up and pulverised. The turning over or inversion which is the distinctive feature of the mouldboard ploughs is not aimed at and, in fact, the objcet is to effect the tillage of the soil without any such turning over, which it is contended is of doubtful advantage if not undesirable altogether. In fact, many tractor ploughing outfits are now coming in, which have only strong cultivator tyres, blades, or points, or discs, but no mouldboard plough bottoms. These only dig the soil or stir it deep but do not invert the soil. At present, however, the implement is something of a novelty and the whole idea may be said to be in the experimental stage. The implement is worked not as a walking or riding plough but only as a tractor plough, both of the usual riding kind and of the garden tractor (walking) kind.

'Multiple' Ploughs.—Ploughs intended for use with tractors or with two or more horses consist of more than one plough bottom with mouldboard or disc. The number may go up to even six. These ploughs are spoken of as "multiple" ploughs; all of them are of course 'riding' ploughs. It is interesting to note that a small bullock-drawn plough with a pair of plough bottoms, has recently been designed at the Indian Agricultural Research Institute, Delhi, which may be said to belong to the "multiple" type, though simple, light and a bullock-drawn walking plough.

WHEN TO PLOUGH THE SOIL

The time or stage at which the soil should be ploughed is mainly decided by the moisture content of the soil which should be such that it will greatly help the passage of the plough through the soil, that is to say, lessen the draft as much as possible and at the same time also tend to reduce the ploughed soil into a loose coarse crumbling mass. If the moisture is below this limit, the ploughing is hard work; if it exceeds the limit the soil becomes pasted together and

may on drying make the clods set into very hard lumps, and thus defeat the very object of the ploughing. This will happen especially in the case of clayey soils and also on the red so-called lateritic soils as those in Mysore.

Such moisture should moreover be present throughout the depth proposed to be ploughed. If it is not present to this depth and if, on account of the season, the ploughing cannot be delayed then a shallow ploughing, working only the top few inches can be ploughed and a later rain awaited to complete it by ploughing the full depth. Generally, if the moisture is such that a small quantity of the moist soil taken and pressed into a handful will keep the shape but can easily fall apart into loose soil if dropped down, the condition may be taken to be just correct for ploughing.

As the moisture is to be provided only by the rainfall (except in the case of irrigated cultivation when it will be possible to wet it sufficiently by irrigation) and as different soils require different quantities of water for moistening them to the condition fit for ploughing, the same rainfall may not be enough for all types of soils. The rainfall for a sandy soil is much less than for loams, which may be less again than for the clayey loams or clayey soils. Soils with a large clay content or soils which are apparently loamy but which contain colloidal clay, and especially of the ferruginous types and those with alkaline admixtures require much care in judging the stage when to plough. After a soaking rain to give them plenty of moisture, they will have to be allowed to dry to just the moisture content when they can be broken up by the plough; they may break only into large lumps but this is unavoidable, but they can generally be broken up for good tilth at the subsequent ploughings. With the mouldboard ploughs especially, the risk of the soil particles being pressed together and made to cohere too much is rather great and an ordinary good-sized country plough is often an advantage for this type of soils.

The black cotton soils are rather different; though they are sticky when wet they do not dry hard, so that even when the clods are raised in large lumps they break down on drying and crumble with the second ploughing or cultivating. As a matter of fact, these soils are so loose and crumbly at the top that ploughing as an annual operation is often dispensed with and only a heavy cultivator or harrow is worked instead.

Depth of Ploughing

It is an observation frequently made that the low yield of crops in India as compared with many other countries is due to the fact that the Indian plough merely scratches the soil and that therefore ploughs capable of ploughing deep should be introduced as one of the main improvements. Even in other countries the question of the depth of ploughing is often discussed. How deep then should soils be ploughed?

That crops thrive better on fields that have been dug, that is to say, stirred or loosened to a greater depth than usual in ploughing, is a well-known fact. Gardeners dig the soil deep, say, up to a foot or 18″; many field crops grown on a garden scale like potatoes, onions, beans, turmeric, ginger and many vegetables, are cultivated thus on soil prepared by digging. Even in field crops grown under ploughing in the ordinary way, if the previous crop should have been grown in a system of trenches and ridges, the rows in which the trenches lay in the previous crop can always be made out by the more luxuriant growth of the succeeding crop on it. In rice fields it is often necessary to lower the level of the fields periodically and this is done by digging long wide trenches and removing the earth out of these and then filling them up with the soil from the adjoining untrenched strips. In the next crop of rice on the field, the strips where the trenches were dug become very conspicuous by the strikingly better growth of the rice in contrast with the adjoining strips. It is obvious therefore that a greater depth of loosened soil will tend to better growth. But field husbandry is different from gardening and practical considerations will largely influence and decide the question. In the case of depth of ploughing these will be mainly (1) the power available, *i.e.,* the quality of the draft animals, (2) the strength and materials of which the ploughs are made, (3) the nature of the soil, *i.e.,* its uniformity and physical condition influencing ploughing.

For instance, a greater depth of ploughing will be possible where horses are used than where bullocks have to be used, as likewise among the latter themselves, greater depth will be possible with larger and heavier bullocks than with small-sized ones. Similarly where only wood is available as the material for ploughs the stregnth necessary for greater depth of ploughing cannot be secured in the ploughs. The power available, *viz.,* the first condition really sets the limit in practice to the depth possible.

The next condition, *viz.,* the condition of the soil in reference to the ease of ploughing and the desirability of deep ploughing, will operate even when the first two conditions are favourable and will apply universally. If, for example, ploughing rains are always meagre, it will be almost impossible to plough the field any deeper than the moisture in the soil will allow. It will be found that even after what may be considered a heavy rain, the soil is not moistened to anything more than about 3″ or 4″, and ploughing cannot therefore be deeper. Many other factors like the great slope of the surface and the large run-off, and the hardness of the soil will act in the same direction and reduce the depth which would be otherwise possible if all the rain soaked into the soil. Many soils may not be of uniform quality beyond a few inches in depth; the lower layers may be less fertile and in ordinary cultivated fields the yearly practice of shallow ploughing that has been going on for many years, has made only the few inches of the ploughed top soil a good fertile

medium, well-tilled and manured, for the roots of the crop. It may not be desirable in this case to plough deeper and mix the poor soil with the rich. This will be much more undesirable in the case of ploughing with mouldboard ploughs, which have the peculiarity of inverting the soil and therefore bringing up the poor soil where it dilutes the good soil, with greater chance of harm to the roots of the crop.

The depth of ordinary ploughing with the local ploughs is however too shallow, even when everything is said in its favour and it is imperative that the depth should be increased. If the stirred soil from a field ploughed with a country plough is pushed aside and the depth of the furrow examined it will be surprising what little depth has been ploughed, although the ploughed surface itself gives a very deceptive idea of the depth. For this purpose, the depth should be increased little by little every year, so that no harm, if any, may result from the sudden change in the depth. A gradual increase until quite 6″ of unmistakable depth is attained is very desirable. Moreover even in the case of local ploughs what is called a plough 'pan' or very hard surface just below the usual depth of ploughing may form, especially where the plough bottom travels flat over the furrow. This is more usual in the case of the mouldboard ploughs, and at intervals of a few years it will be necessary to plough into this hard layer and break it; a plough of the local type or an iron plough which has only ploughing point like a coulter but no flat share and mouldboard will have to be used for the purpose. A special plough called the "subsoil plough" or "subsoiler" is made for this purpose but a strong local plough which will plough deep enough to break the pan can also be used.

Some Special Ploughs

Among these are the plough called a Subsoil plough already referred to, the Ridging plough and the Harvesting ploughs for potatoes, beans, groundnuts, etc. The 'subsoil plough' has only a strong cutting point like a coulter as its working part and this forms its plough bottom so to speak. Its work has already been described. The 'ridging plough' is a kind of double plough, there being a share and mouldboard on either side of the plough. When it works, it makes a large deep furrow and pushes the soil on both sides (instead of only on one side as in a regular plough); so that between one furrow and its neighbour there is formed a fairly large and high ridge. The worked field is thus left with deep furrows and high ridges alternating. It is used, of course, only after the field has been thoroughly ploughed and prepared in the ordinary way. For the planting of sugarcane or of potatoes on a large scale, where planting is in furrows which have to be otherwise made by hand, this plough will be a great labour saver. Later on, cattle manure can be applied in the furrows and the ridges can be split, covering the furrows and

converting them into ridges and *vice versa.* The ordinary country plough is indeed a rough kind of ridging plough.

The 'harvesting ploughs' are made similar to the mouldboard ploughs but are provided with a set of long prongs like a grid where the mouldboard should be. Worked in a potato or groundnut field ready for harvest, the share cuts below the tubers or nuts, raising both soil and produce up the grid and throws it aside; the earth falls through the grid while the produce more or less freed from the adhering earth is brought up ready for gathering on the top of the surface. On light easy working soils these are found useful, but for the thrifty Indian ryot it is wasteful, because appreciable quantities of the crop are left behind and portions are also damaged. In the case of groundnuts moreover the soils are too hard at the harvest time to allow of such ploughing, except where the field can be given an irrigation.

The Draft of Ploughs

The draft of ploughs is the force required to work a plough through any particular soil, and is a measure of the difficulty or strain involved. It will naturally vary with many factors, such as firstly, the kind of soil and its moisture content, secondly, the depth of ploughing and thirdly, the kind and quality of the plough, the style of the mouldboard, the hardness and finish of the surface, and lastly the method of hitching the animals. The draft is generally measured by means of a regular dynomometer, or merely by a spring balance and is expressed in terms of pounds per square inch of cross-section of the furrow. Tests of the draft of ploughs have been made on many soils with mouldboard ploughs both in England and in America and it has been found to vary from about 13 lb. down to about 5·5 lb. per square inch of the furrow section. In stiff clayey soils it reaches the upper figure and in light loamy soils the lower figure; on average loams the draft is taken as about 6 lb. per square inch. On hard soils with not enough moisture it may go up to double the draft required on soils in a fit condition for ploughing. Depth, style of mouldboard and other factors also make considerable differences. With ordinary Indian country ploughs the total draft in the average may amount to 200 lb. to 250 lb. which should be considered very high, for the size of the furrow usually ploughed, as this will work out to 10 lb. or 12 lb. per square inch.

Some Forms of Special Ploughing

While the above considerations apply to what may be called general ploughing there are some special kinds which are also important in India. These are (1) puddle ploughing in rice fields, (2) hot weather ploughing on black cotton soils, and (3) to a lesser extent, the ploughing after harvest or autumn ploughing.

1. *Puddle Ploughing for Rice Cultivation*

Rice cultivation is conducted in two ways, in one of which the land is prepared in the same way as for dry crops, and water is impounded only after the crop has been sown and has made considerable growth, and in the other, the land is flooded right from the beginning and the preparatory ploughing is itself made in the puddle. In the latter case ploughing is much easier than in the cases considered so far, *viz.,* in dry land ploughing. The field is watered sufficiently and thoroughly softened before the plough is put on, and therefore the first ploughing which is always the most difficult becomes very easy in this case. Small-sized bullocks are found quite enough for the work and it is a characteristic of rice tracts that the bullocks are usually of a smaller breed. Likewise ploughs are also of small size, especially on account of the ease of ploughing, and as the soil has to be cut and moved about only in the puddle even the local country type is found sufficient. The action of the plough is not only to cut the furrow slice but to reduce it to the shape of very fine grains so that the latter may mix intimately with the water. The process is more a stirring up and not a kneading as in a pug mill; the soil particles in the puddle run loose more or less and when the ploughing is stopped, the particles will separate and sink if left undisturbed with the water above it. The condition is that of an oversaturated soil, with the pores filled to overflowing with water; but the soil grains are still apart and not pasted together as if they were kneaded together. There should be the same facility for the easy traversing of the soil by the roots as in the case of other crops, the only difference being that the rice roots can flourish when fully bathed in water while the others cannot. In order to reduce the soil to this condition repeated ploughings are necessary; and during the intervals some of the coarse vegetable matter like the stubble, or weeds, etc., rot and disintegrate. In view of the need for repeated ploughings or stirrings which are thus required, there is no special advantage in using mouldboard ploughs in preference to local ploughs, as the chief merit of the former is the saving in the number of ploughings. As rice is grown on practically every conceivable type of soil, including those which are moderately alkaline, or very clayey or boggy, ploughing will be difficult under these conditions and in extreme cases men and animals may sink too deep in the soft and almost floating mud, and great skill will be required in ploughing or stirring in such soils.

Few improvements by way of expediting or lightening the work of puddle ploughing have been attempted but recently an implement which is claimed to effect much saving in time and labour has been designed and its use suggested. The implement is drawn by one pair of bullocks and works a width of about 3′ as it is drawn over the puddle. Three sets of blades each comprising four blades are mounted radially on the periphery of a large wooden

roller which turns on a central shaft; the blades work into and puddle the soil one after the other as the roller is moved along the field. It is claimed to be a great labour-saving device and costing only Rs. 15 (*Indian Farming*, March 1943). Similar 'puddlers' and 'tramplers' for trampling or working in of green manure made by Messrs. P. S. G. & Sons, at Coimbatore, are reported to be coming into use.

2. *Hot Weather Ploughing in Black Cotton Soil Fields*

One of the main difficulties in the cultivation of the black cotton soils is due to the deep-rooted grass *hariali*, or *dub* (*Cynodon dactylon*) which grows as a weed and spreads year after year. This grass is found greatly detrimental to the cotton crop, acting almost as a poison to the cotton roots and reducing the growth and the yield of the cotton crop. Ordinary weeding operations are not effective on account of its deep roots and underground creeping stolons which root all along as they spread. The only way in which the field can be cleared is to dig to a depth of at least 1′, expose the clods with the roots of the grass to the sun during the hot weather months, break the clods and free the roots therefrom to be gathered and burnt. By this process, the field is kept clean for a period of some five years at least if the work is done thoroughly. As the digging is both slow and expensive, a heavy deep working plough is used instead. Until recently only large heavy wooden ploughs specially made for this work were being used; this was a wooden plough of the ordinary local type but very much larger, with the tip of the ploughing wedge (or coulter) quite 1′ or more below the line of the elbow bend near the handle and therefore capable of ploughing this depth as a maximum. This plough will tear through the soil breaking the roots of the grass and throw up the soil in large clods, the wide interspaces between which allow of thorough drying up of the roots. The work is very hard and some 6 or 7 pairs of strong bullocks are generally hitched and as many workmen are also required.

The chief points to be attended to in this ploughing are: (1) the ploughing must be done at the commencement of the hot weather, usually from the month of February onwards, so that the greater part of the hot weather months may be available for the drying of the roots; (2) the ploughing has to be deep, the deeper the better; usually 1′ is attempted, if not 18″. This 18″ depth is always insisted on when digging is resorted to, except where the soil is not deep and soft decomposed rock is met with, which in these tracts is not unusual. Generally however as the black cotton soil is deep and uniform in quality there is no risk of raw soil being brought up by the deep ploughing; (3) the natural tendency of the soil at this stage is to break into big clods should be taken advantage of, because the heavy clods help in tearing off the roots by their weight and wide

interspaces are left in which the hot summer air can play freely and dry up the roots.

Iron and steel ploughs of the mouldboard type have come into use largely for this purpose. The action of the mouldboard in pushing aside to one side the clod from the furrow farther than in the wooden ploughs is an advantage as it facilitates the drying up of the furrow bottom and the clod. The popular iron ploughs are of the turnwrest type, chiefly because the trouble of walking on the rough clods is shared evenly by the bullocks on either side of the plough. Many of the locally made ploughs also have the necessary weight, though neither the share nor the mouldboard have the smooth surface needed for effective scouring. This however is not much of a disadvantage as the soil at this stage does not much stick to the surface of the plough.

The Use of Power or Engine Ploughs for Black Cotton Soil Ploughing.—As the use of engine power for ploughing has been attempted in the case of this kind of black cotton soil ploughing on many occasions, because for that work the indigenous method of ploughing with bullocks has been found very slow and laborious and a substitution of engine power is therefore genuinely called for, and will be welcomed, reference may be made briefly to some of the difficulties which have been experienced in this connection.

The ploughs used for the purpose have been large mouldboard ploughs whose peculiar feature is width of furrow rather than depth. Ploughs with even 14" bottoms have been used but they have lacked the depth which has been only some 9". This depth however is not sufficient for the special purpose in view, and a depth of 10" to 12" is quite necessary, on most of soils. Both ordinary ploughs and 'turnwrest' ploughs have been tried. The former (the ordinary ones with fixed mouldboard) has been used in the case of direct traction by means of traction engines, which draw the plough as they travel forward over the field and do therefore the work of ploughing and that of propelling themselves simultaneously. The 'turnwrest' plough (a large balance plough) has been employed, and these were drawn by stationary steam engines by means of steel cables, the engines moving forward only after the plough finished one journey and so utilising their full power for the purpose of pulling the plough. The outfit was the well-known Fowler double engine ploughing equipment. These ploughs have been found to plough the necessary depth and have in this respect been satisfactory. As the ploughing arrangement (*viz.,* the ploughing by the balance plough) involves no turning around, work is simplified and is speedier to that extent.

The work is very difficult, in fact, more difficult than what ordinary ploughing tractors are designed for, and much higher power is needed. Even then only two plough bottoms can be used and anything larger will be too difficult. With ordinary traction engines, even when the strain is lessened by thus hitching only two bottoms there are frequent breakdowns, as some part or other gives way and

has to be replaced. Engines have to possess not only sufficient power to pull the ploughs but also an abundant reserve against unforeseen difficult patches and requirements. In addition to power, weight is also important as with light tractors the machine has been found to rear up when the pull becomes too great. The tread is also quite important for the same reason and caterpillar styles have this advantage in addition to others, like travelling on soft or uneven ground. The rubber tyres now provided for large tractors will probably be found unsuitable for the work in this respect, not giving the required grip on the surface; experience is of course lacking because these are recent improvements. The author has however seen the rubber-tyred wheels of the recent high-powered models slipping badly in difficult patches of ploughing and the wheels simply spinning away with the tractor straining and at a standstill. It is reported however that this is exceptional and that the rubber-tyred wheels are quite satisfactory for this work. Much has been learnt by the experience of the earlier trials and engines with a higher H.P. are now used and the last war has brought out very powerful types (needed for the bull-dozers, work of levelling, digging, etc.). Not only is a much higher H.P. required (such as at the rate of 15 H.P. now usually provided per plough bottom used) but in addition, plough, plough parts and the whole tackle in fact should be as strong and sturdy as can be made and the ploughs designed for a depth of at least 12". It is the frequency of breakdowns added to the lack of sufficient depth with the tractor ploughs so far that have discouraged the use of tractors and have deprived the method of its undoubted and much desired advantages.

The steam ploughing tackle, though it performed the work satisfactorily, suffered from other drawbacks, such as, firstly, the need for coal fuel in out-of-the-way places, secondly, the need for ample supplies of water for the boilers in the black cotton soil tracts which are notoriously short of even drinking-water and thirdly, the quality of such water as is available, which is too impure with both suspended and dissolved matter, causing a heavy scale deposit in the boiler and tubes. Steam engines therefore, though otherwise suitable, cannot be thought of for the above reasons. Powerful tractors working on crude oil are those which appear to hold out promise, in any general scheme for this kind of work. Many such have now largely come into use and their number is likely to increase. The use of charcoal gas has now become very popular in the case of motor vehicles in recent years and deserves to be adapted to tractors also. The generators are made in the country and charcoal is also obtained locally, so that there is no dependance of foreign fuel; it is also likely that running costs will be low.

As regards the plough itself, a somewhat novel implement called the Spalding Deep Tillage Implement was got out many years ago by the Mysore Department of Agriculture. This consists of two large disc ploughs one mounted behind the other, and both working in the same furrow. The implement therefore does not

plough two plough furrows but only one single very deep furrow; the fore disc ploughed 9" (that was the claim) and the rear disc worked in the bottom of the furrow made by the fore disc and cut (or claimed to be cut) a further 9", so that the total depth of ploughing would be 18". The implement was also intended for animal traction. The soils both red and black at least in Mysore are too hard for penetration by the discs and the implement was never found to make good the claim and had to be discarded.

On the whole it would appear that strong mouldboard ploughs capable of ploughing up to 12" or more and drawn by a sufficiently high-powered and heavy tractor of the caterpillar type or provided with wide lugs on the wheels for effective grip, and working on crude oil or charcoal gas is the kind of equipment which may be found most suitable. Of the need for this kind of machine ploughing there is no doubt and the scope for profitable use is great.

The subject of the use of tractors in Indian Agriculture is further dealt with separately, *vide* Chapter on "Other Implements and Machines".

3. *Autumn Ploughing or Ploughing after Harvest*

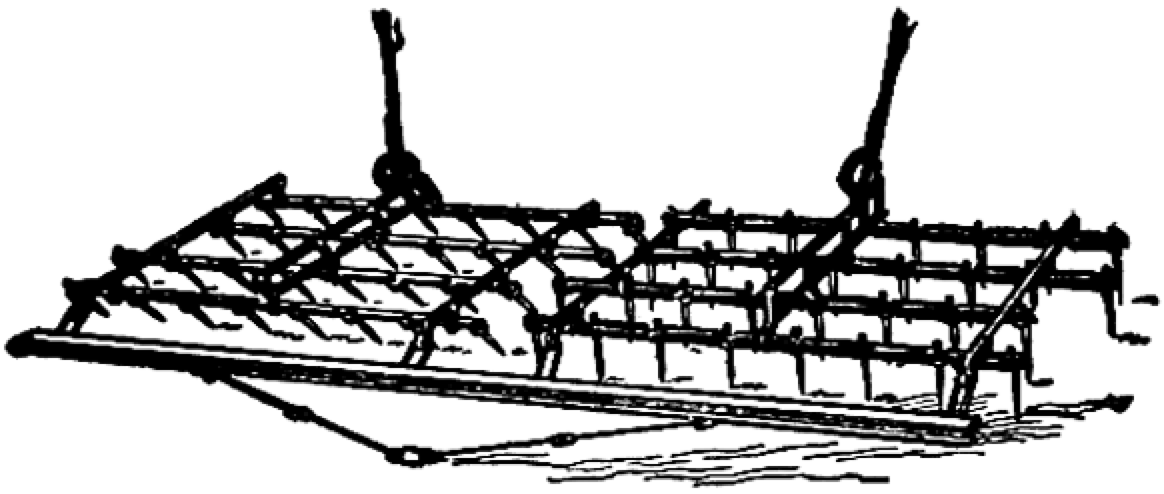
In the case of the dry crop which are harvested about the month of November-December, it has been found that if the field is ploughed immediately or as soon as possible after the harvest and left in that condition through the hot weather months, the subsequent crop is much benefited. This has been found by experiment to be the case in respect of the ragi crop in the Mysore State. It is also the general belief among cultivators that such ploughing is very beneficial and that it amounts to a manuring. Many causes may be responsible for the result such as the conservation of moisture in the lower layers, the weathering of the soil in a more effective manner, killing out of certain weeds and insect pests, greater bacterial action and the ability of the soil to absorb the very first rains by permitting it to soak in better and reducing the run-off which may occur on unploughed ground. It is not possible to say which of these conduces to the result and to what extent. In practice the last mentioned, *viz.,* the increased intake of the rainfall and the ease in preparing the soil is the feature which is greatly appreciated and in the case of dry farming this is very important. The ploughing is however difficult as the surface of the field is fairly hard at this time and the longer it is delayed after the harvest the drier the soil becomes and the more difficult the ploughing. Although a good ploughing to the ordinary depth is what may be very desirable, it has been found that even a loose soil mulch as may be produced by a cultivating tool will be a great advantage and should be preferred to leaving the soil untilled. Depending upon the condition of the soil and the degree of difficulty in ploughing, this form of tillage may therefore be conducted by a shallow plough or by the local heavy harrows or *kuntes*, or by a disc

harrow set as deep as it can go. On the black cotton soils the bladed *kunte* or harrow which is used for this purpose has also the effect of closing up the somewhat deep cracks which always develop in this type of soil during the hot weather.

WORK TURNED OUT BY PLOUGHS

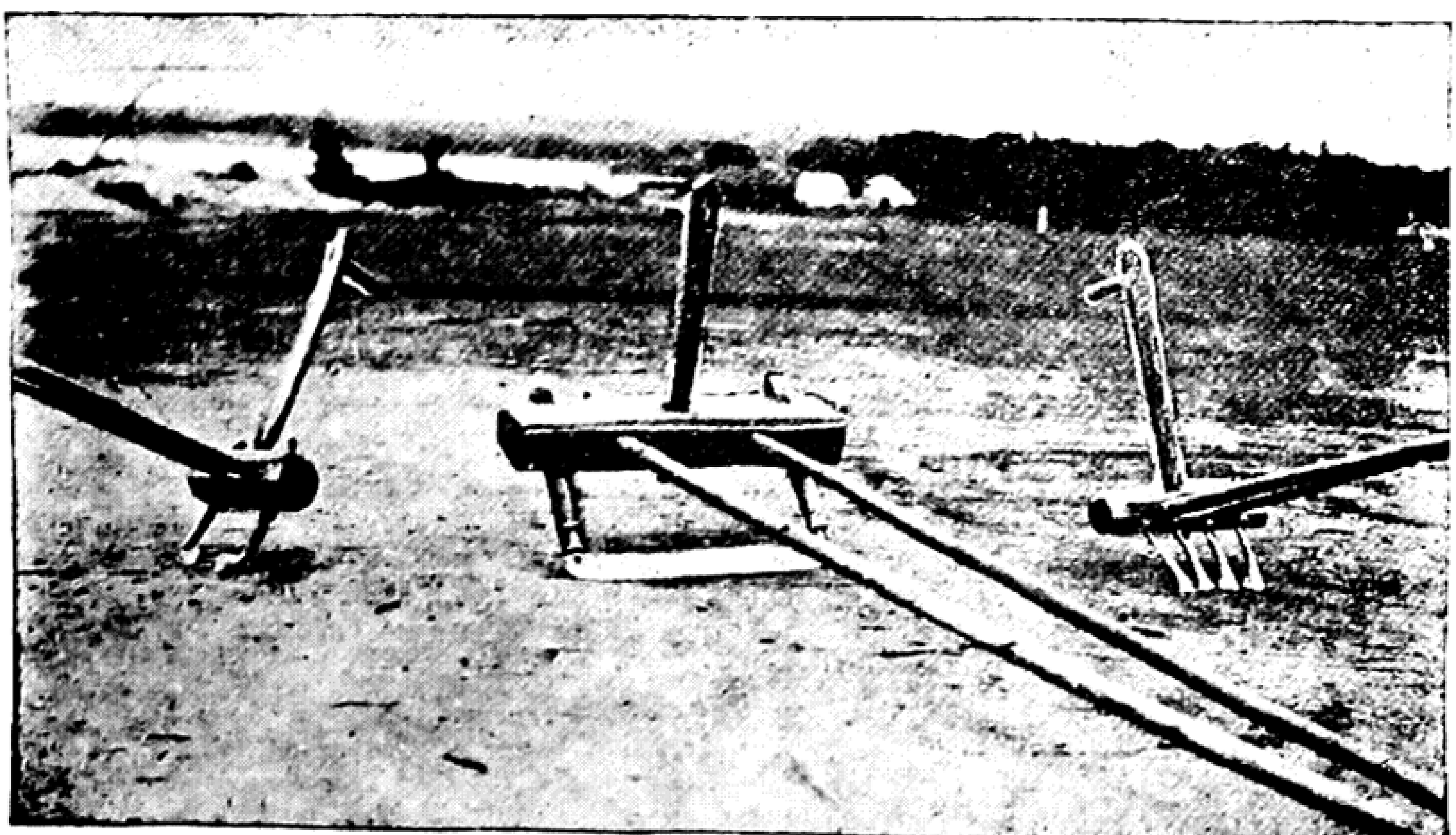
The outturn of ploughing work turned out by the various ploughs and under different conditions and kinds of ploughing will naturally vary according to circumstances. In ordinary red loamy soils of average difficulty and when the ploughing is taken up after a good soaking rain the local ploughs will cover an area of one-quarter to one-third of an acre a day in the first ploughing. With these ploughs the work has to be closely watched to see that the furrows are close together and no interspaces of unploughed ridges are left. In the subsequent ploughings the area will be more and may amount to two-third or three-quarters of an acre per day. At least three ploughings will be required to plough the soil thoroughly without any unploughed little bits of ridges remaining anywhere. Heavier bullocks may do a little more but in that case a heavier plough is also used and the area is about the same though the depth may be a little more. A mouldboard plough of the K.M. type will plough a furrow about 5" wide and will do with ordinary bullocks about one-third to half-an-acre per day. The outturn per hour will be a more useful figure, as work hours vary much in different tracts according to custom. It is easy to calculate the area ploughed per hour approximately in the following manner: If the furrow is 1" wide, then an acre will require 99 miles of furrow length to be fully covered; if then the width of the furrow is, say 4", then the furrow length will be nearly 25 miles. As a pair of plough bullocks cannot walk faster than $1\frac{1}{2}$ miles per hour in ploughing work this will mean about 17 hours of ploughing. Allowance has however to be made for time lost in turning and this may take about 3 hours in all, so that an acre can be ploughed in about 20 hours of work or three ploughing days at the rate of about 6 hours of work per day. In the case of a 6" furrow it will be $16\frac{1}{2}$ miles of furrow length and with other sizes of ploughs it will be in proportion. If a tractor draws two large 14" ploughs it will cover 28" at each journey and should travel about $3\frac{1}{2}$ miles to cover 1 acre. As it can travel at that speed, an acre can be ploughed in that number of hours or making allowance for turnings in about 4 hours. Turnings can be reduced if long furrows are ploughed; the longer they are the less the loss in turning, a fact which has already been referred to.

In the case of puddle ploughing on rice land work is very slow as the bullocks can walk only very slowly in the soft mud, in spite of the fact that the ground is not hard at all. The daily outturn may be about one-fourth of an acre for the first ploughing and one-third for the second.



Spike tooth lever harrow, two sections; the first section is set as a smoothening harrow.

Mys. Agr. Dept.



The large bladed harrow Dodda kunte (in the centre) and two types of interculturing hoes.

Photo by Courtesy of the Mys. Dept. of Agric.

Hot weather deep ploughing on the black cotton soils for destroying Hariali (*Cynodon dactylon*) grass with a heavy iron plough drawn by six pairs of bullocks.

Photo by Author

AMOUNT OF WORK TURNED OUT BY OTHER TILLAGE IMPLEMENTS

The amount of work that can be turned out by the different implements of tillage dealt with in this section can be calculated by this same method; the width of the ground covered at each journey of the implement and the speed of the bullocks or tractor being known. While ploughing is both slow and difficult because of the small width of the furrow or ground worked at each journey and the hardness of the ground, the subsequent tillage operations are both easy and quick. The bladed *kuntes* (*bakhars*) and cultivators work about 2′ width of ground and the lighter harrows work about 3′ width of ground. The wooden harrows, the levelling boards and logs or rollers are wider still and the work too is light and the bullocks can walk faster. The work turned out per hour will therefore be very much greater; for instance, with a 4′ tool of the latter group of implements, in acre will mean a distance of $\frac{99}{4 \times 12}$ or about 2 miles and as the bullocks can walk 2 or $2\frac{1}{2}$ miles an hour in this class of work, an hour's work may amount to 1 or $1\frac{1}{2}$ acres.

TILLAGE OPERATIONS FOLLOWING PLOUGHING AND IMPLEMENTS USED THEREFOR

After the ground has been broken up by the plough, the next operations bring about the following, *viz.,* (1) the breaking of clods and reducing them gradually to smaller lumps until the soil becomes an aggregate of particles of which a well-tilled soil is composed. (2) The freeing of the roots from the soil clods in which they are firmly held. (3) Bringing them up to the surface for being gathered. (4) Gathering the stubble and roots and removing them from the field. (5) The levelling of the surface. (6) The compacting of the soil surface, when too loose.

1. *Cultivating Tools*

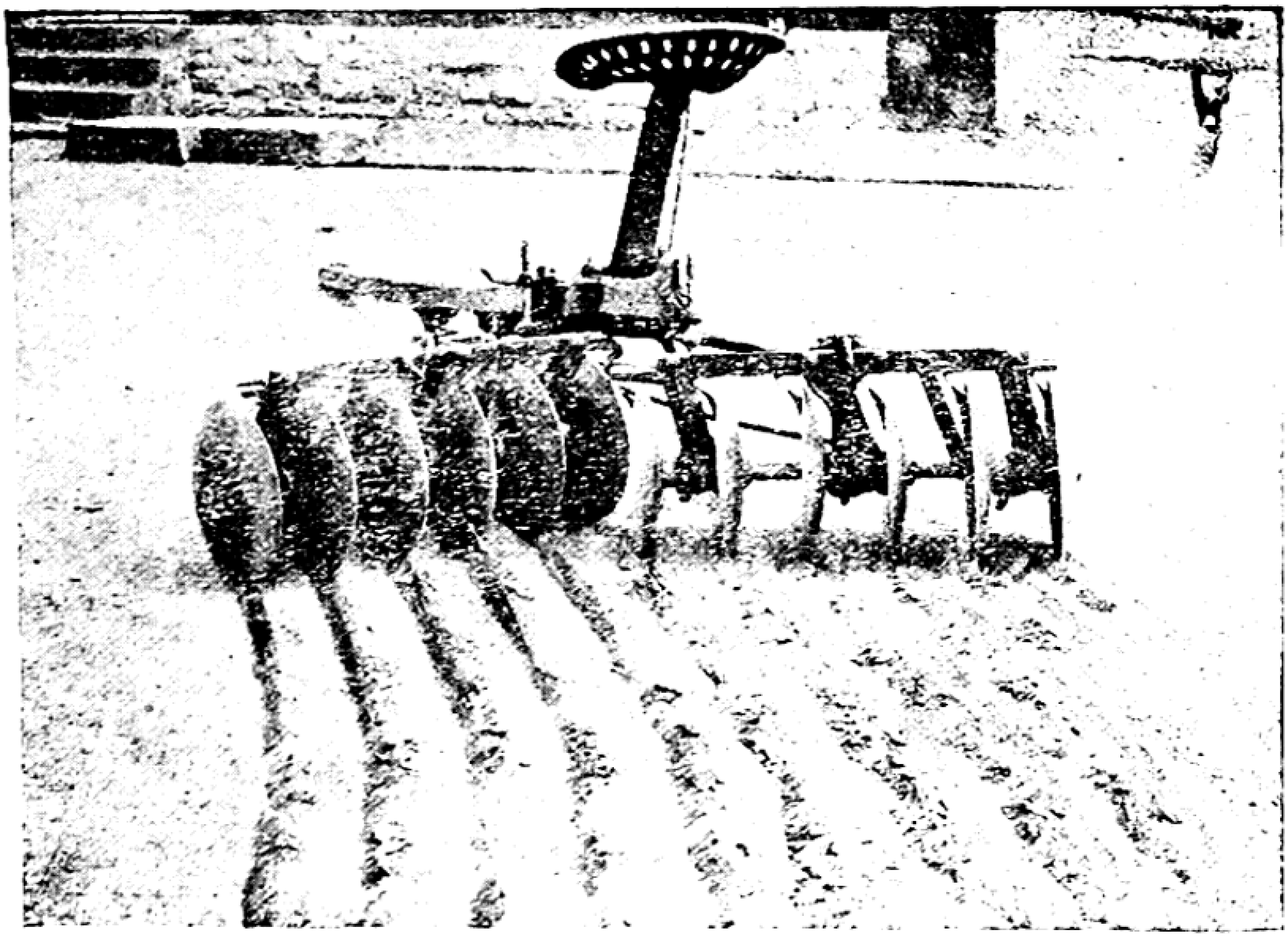
The breaking up of the soil clods is brought about firstly by the plough itself. A cross-ploughing generally follows the first ploughing and where local wooden ploughs are used, ploughings are repeated several times. All these have the effect of breaking the clods considerably. The work is done more economically by the use of cultivating implements. These have either teeth or tynes or consist of one long cross blade. The bladed type of which there are several sizes (called *kuntes* or *bakhars*) does the work best; the blade cuts through a wide strip (18″ to 24″ according to size) of the ploughed ground and the clods are also crushed in passing between the blade and the wooden beam or timber which forms the main frame of the implement. The toothed or tyned cultivators can be used only when the clods easily fall apart or when one or two cross-ploughings have already been done; they will also cover

widths according to their size. The tynes are straight or curved and in the latter case may be rigid or have a spring action. One implement with rigid and curved teeth (called the K.M. six shovel cultivator in Mysore) is a fairly efficient implement for this purpose; it works a width of 3′ and the tynes are fixed in two rows of three tynes each, one behind the other, the tynes of the rear row moving between the tynes of the front row and thereby avoiding any choking. Those with a spring action have the effect of shaking the clods as they become broken and thereby releasing the roots better, but on account of the lack of rigidity the breaking is not effective. On the whole, considering the cheapness, efficiency and simplicity, the local *bakhar* type is best for this purpose. The breaking of the clods is helped by the action of the weather, especially a shower of rain, which in this country is the most helpful factor; the cultivating tool must be put on the land at the correct stage when the crumbling will be easiest.

Rollers.—Where coherence between soil particles is greater as in those with more clay in them, the clods are difficult to manage by cultivators alone and special clod crushers have to be used. These are small rollers (like lawn rollers) made of wood or iron, the former being the kind used in India. The rollers are either entire or consist of two sections, have a plain smooth surface or are made up of a number of heavy rings put together which gives the surface a grooved or fluted appearance. Rollers of either type can be made also of cement concrete. The condition of the soil should be noted carefully before putting on the roller, the clods should be fairly dry lest any pasting or cementing action should take place. After the clod crushing roller has worked, a cultivator should follow, both to help the breaking of the clods and to loosen the compacted surface.

Levelling Boards or Logs.—A plain log, either a mere rough heavy plank or one fashioned and scooped out so that it is semicircular or trapezoidal in section or a set of planks placed lapping over each other and bolted together is often used, which both levels the soil and smoothens the surface and also does some clod crushing. This log or levelling plank is however used at a later stage after the clod crushers proper.

Disc Harrows for Tractor Work.—In tillage with the use of tractors, this kind of work is performed by disc harrows, of which a double gang is used one behind the other. The fore set has the discs facing one way (outwards or inwards) and the rear set has them facing the opposite way, so that the clods are in effect cut and crushed as they would be if they were taken and crushed between the hands. The discs may be either with entire rims or of the 'cut-away' type in which the rim has a deep wavy margin, regular alternate portions being cut away. Disc harrows of all types can be adjusted to work deep or shallow by setting the two arms of the harrow either straight in a line with each other or at an angle, the narrower the angle the deeper they work. The implement may also



Disc Harrow, suitable for working with a pair of bullocks.

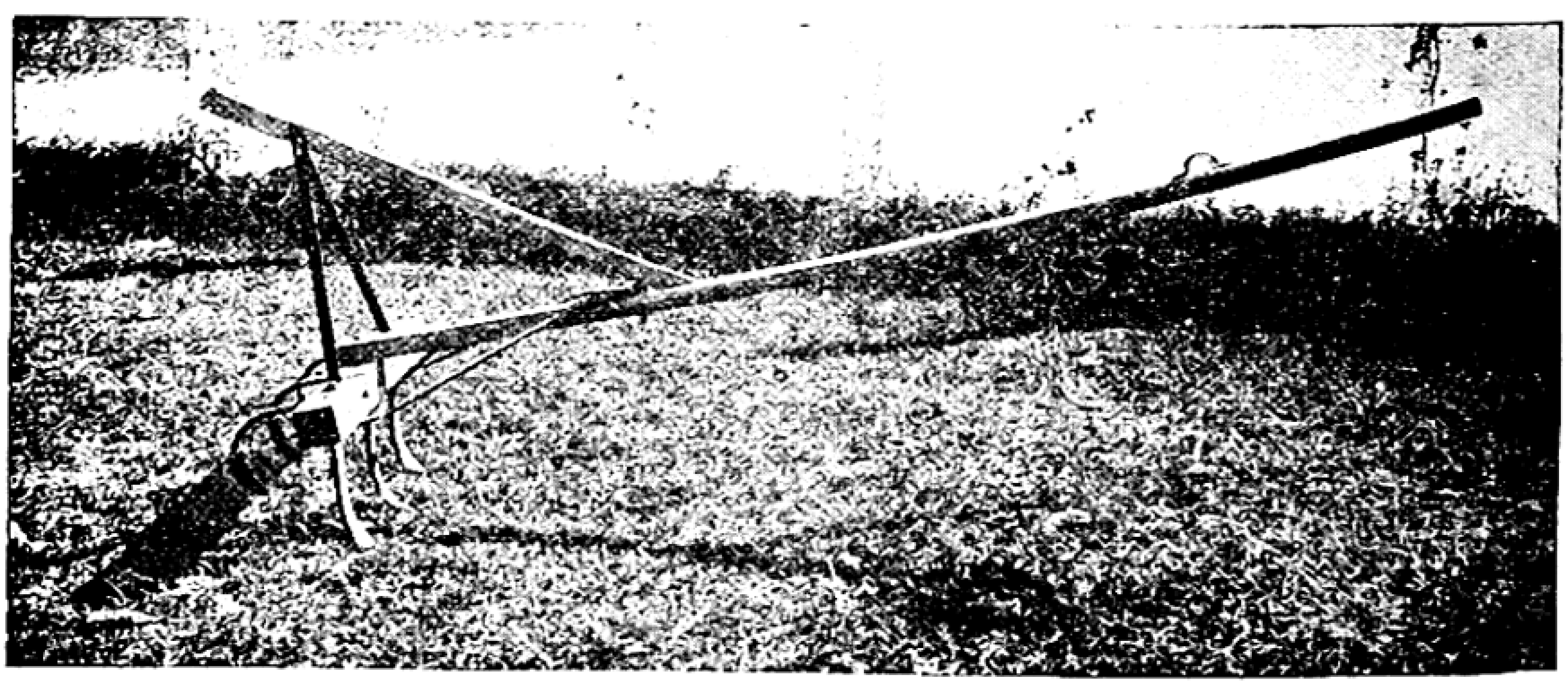
Mys. Agr. Dept.

A cold crushing roller made of reinforced cement concrete. A very serviceable implement made and in use at the College of Agriculture, Fort Collins, Colo., U.S.A.

Photo by Author

The heavy bladed harrow called **Dodda kunte or Bakhar,** working on the black cotton soil, with the driver standing on the frame to add weight.

Photo by Author



The Kolar Mission Six-shovel Cultivator, a very useful labour-saving tillage implement, popular in the Mysore State.

Mys. Agr. Dept.

be weighted when necessary for the same purpose, with stones, old rails or a sandbag and usually there is provision on the top of the frame for carrying these weights. The disc harrows are essentially for tractor work, being too heavy for bullock draft, but smaller models are also available, containing either 3 or 4 discs of moderate size in each arm and working a width of about 5′ or 6′; but even these mean hard work for bullocks, and especially so as they have to walk over the clods in a ploughed field.

Other Harrows.—The clods having been broken with these implements (helped by the weather in the intervals) and the roots of the stubble and weeds freed, the latter have to be brought up and gathered. The cultivators used for clod crushing do this work at the same time to a large extent and subsequent work is one mainly of gathering them. For this purpose harrows of different types are used which more or less imitate the action of the fingers in gathering the roots. In addition, the harrows break the lumps of soil further, producing a finer tilth and smoothen and level the surface. Local harrows are of the bladed type or of the toothed type. Both are very light models, the former has a very narrow blade but much longer, about 4′ or more in length. The toothed harrows are however more satisfactory for this kind of work. The teeth are only rigid wooden or iron pegs about 9″ in length mounted in a row on a straight timber and generally about 6′ in length, the teeth being fixed 4″ to 8″ apart. The teeth may be made heavier somewhat like cultivator teeth, for working a little deeper than the lighter ones, which latter practically skim the surface and are only smoothening harrows.

In other types (mostly improved and imported patterns) the teeth are fixed in three or four separate bars of iron (flat bars or U sections) one behind the other in a kind of rectangular frame. The frame may be made triangular, or to have an S or Z shape. In all of them the teeth are so set that in each row they are fairly wide apart but that no teeth are exactly one behind the other in a line. By this 'staggered' arrangement the choking of the implement as it moves along gathering the roots, etc., is avoided largely and at the same time the general effect is like that of a comb, as the tracks made by all the teeth together are very close to each other. Even the best harrows will have to be lifted frequently as they move along so as to get rid of the accumulated roots and weeds, and it will be helpful if this lifting up is made at regular intervals so as to facilitate removal or putting up larger heaps for burning.

Lever Harrows.—The teeth in some types of these harrows are adjustable for depth of working, by means of a lever which make the teeth point forward and work deeper or point backward and act merely as a smoothing harrow or remain fixed vertical as a soil stirring or ordinary harrow. These lever harrows and all the improved types are made in two or three sections and they are worked either singly or in two's or three's according to the difficulty of the work

or the quality of the bullocks used. The teeth in most harrows tend to become loose, when at work, and they should be tightened promptly by screwing down the nuts, or by driving thin wedges.

Compacting the Seed-Bed.—The weeds and roots gathered up by the harrows are usually burnt on the field itself, if they are dry enough, or removed from the field. In the former case the ashes are spread on the field by hand and by another harrowing which may follow. A certain amount of smoothening and compacting of the soil for producing a firm seed-bed is effected by working the levelling log referred to already. Such a firm seed-bed is necessary for the sprouting seedlings and the moisture content of the seed-bed is increased by the rise of capillary moisture from below by the process. Much is claimed for this kind of compacting of the seed-bed and a special implement called a "sub-surface packer" has been recommended for the purpose, which will be referred to further under 'Dry Farming'.

In dry cultivation the tillage operations preparatory to the sowing come to a close at this stage, when a satisfactory seed-bed has been produced. In many parts of the country such a variety of implements is not used and the ordinary plough does duty for all of them. In no case however can the need for some amount of manual labour be avoided, because work with implements however labour-saving will still leave imperfections which will have to be attended to by manual labour if the work is to be thorough.

In the case of the cultivation of rice land by the puddling methods no such series of operations are required; the weeds and roots of stubble are all stirred into the puddle in the ploughing itself, which has to be repeated many times as already stated. An essential implement is however the smoothing log, described already. This has to be worked over the puddled soil with the water standing on it principally for levelling the surface roughened by the ploughings and the coarse cattle manure and green manure applied.

Spreading and Working in of Manure into the Soil.—The work of preparatory cultivation includes also the mixing of bulky manures like cattle manure, street sweepings, etc., and soil ameliorants like tank silt, red earth, sand, etc., with the soil. The plough is used for this purpose and the ploughing in of the materials is usually done after the field has been well ploughed and cultivated, but prior to the working of the harrows, levellers, etc. The object is to incorporate the manure into the soil thoroughly, throughout the ploughed depth, and uniformly all over the field, and the details of the operation should be such as to secure this object. The general practice is to cart the manure and other materials, and unload them in cart-loads at regular distances all over the field; they are later on taken as headlocks in baskets and scattered uniformly over the field, after which the field is ploughed once or twice or worked with a cultivator. These and the light tillage which follows thereafter serve to effect a thorough mixing throughout the ploughed depth which is the

root range of the crop. It is not always possible to effect as uniform a spreading as may be desirable in this method, as many spots may be altogether missed or covered too thinly, in distributing the material from each cartload centre over a wide circle. In foreign countries a mechanical manure spreader is used, which ensures greater uniformity in the spreading. The machine is in essence only an open manure cart of special construction, at the rear end of which a cylinder with spoke-like arms revolves, whose spokes or arms throw or shovel out spokefuls of the manure as the cart moves along. Without resorting to any such machine, some improvement can be made in the present manual method itself, if the cartloads of manure are emptied at much shorter distances and in quantities of a quarter of a cartload each, so that the heaps are more numerous and at shorter distances, and the circle of distribution becomes proportionately small and the distribution therefore likely to be more uniform.

INTERCULTIVATION

Intercultivation is the light tilling or stirring of the soil, which is carried out in the field *after* the plants have come up, in between the rows or in among the plants themselves, if the sowing was not done in rows. The operation begins as soon as the plants can be seen above ground and the braids or rows are plainly visible. Hand tools like small weeding hooks are used in garden cultivation, but in field husbandry the work is done by bullock implements. The interculture is carried out more than once at short intervals and comes to a close after the crop has made growth enough to cover the space between the rows. Even where only bullock implements are used, a certain amount of hand weeding follows, in order to make the work thorough and so as to cover ground not touched by the bullock implement.

The objects of interculturing are (1) the removal of weeds as they come up, (2) the thinning of the crop, and (3) the conservation of soil moisture.

Removal of Weeds.—However carefully the soil may have been prepared before sowing, weed growth cannot be eliminated, and a large number come up along with the young crop. Weeds are usually more hardy than the crop and in the competition for space, moisture and plant food in the soil the weeds have the advantage. The sooner such competition is removed, the better it is for the crop. Interculture therefore begins very early; as more weeds come up and as even the first interculture does not remove all the weeds, a second one follows after a week or ten days, and a third one after another short interval. Weed removal has to be thorough, not only for keeping the field clear for the crop but also for conserving the moisture in the soil for the use of the crop.

2. *Thinning of the Crop.*—It may be stated that in ordinary sowing it is unavoidable that many times more plants come up than are desirable and that therefore the young crop has to be thinned

out, so that the stand may not be too thick. This work is effected in the interculturing. If fields are broadcast, then the implements are worked both along and across the field and they destroy all seedlings which lie in the track of the tynes or blades, leaving the remaining plants at the proper intervals of space from each other. Where fields are sown in rows, and in the case of the small grains like ragi, an interculturing is given across the rows also, while in the case of other crops only the space between the rows is worked. If however the stand is too thick in the rows the implement will have to work in the rows also. In practice great benefit accrues from the very early thinning of the crop to the required extent; if the plants have grown up a little such thinning may not be easy and the result will generally be a large number of thin spindly plants crowding each other.

3. *Conservation of Soil Moisture.*—While indirectly soil moisture is conserved, because weeds which greatly deplete the moisture are removed in the operation, interculture tends directly also to preserve the moisture immediately below the depth of soil stirred by the tool. If it were not for the protecting layer of dry powdery soil or soil mulch produced by the interculture, the soil within the root range of the young seedling will become too dry or lose too much moisture and the seedlings may begin to wilt. Even if the content of moisture of this lower layer is not increased by the rise of capillary moisture from below—a rise which is now somewhat doubted—both common observation and soil moisture determinations go to show that the moisture under the mulch remains longer than in the unstirred soil or soil with no mulch. For the tender crop at this stage this is a very important advantage. Incidentally, aeration and the breaking of the soil crust also accrue and are decidedly beneficial.

IMPLEMENTS FOR INTERCULTURE

For manual labour, hand hoes and weeding hooks are used for interculturing or hoeing, the former term being somewhat restricted to the use of bullock implements or those drawn by mechanical power. The local Indian types of hoes are like miniature digging tools (*guddalis*) or like scraping blades. They are only single-pronged or bladed and are short-handled, for being worked by the labourer in a sitting posture. Those with the scraping blades are useful when the soil is somewhat hard. Foreign hoes are many pronged and have very long handles, for being used in a standing posture; they cover a wider ground at each stroke but of course involve more strength. There are also hoes of the bladed type, with one or more small rectangular blades, each suited to a different type of work.

The bullock hoes are of course the more important ones for field crops and the Indian hoes are of two general types. In one (the *yede kunte* or *bakhar* type) the working part is a narrow

blade about as long as the width of the row to be intercultivated, and in the other type is either a set of two L-shaped flat iron bars facing each other and resembling a small hoe of the bladed type with a split or gap in the middle, or a set of two vertical teeth with the ends flattened into blades. The first type is very useful in drill sown crops, as it cleans up in one journey the full width of its track, cutting down under the roots of the weeds as it stirs the soil. It cannot be used for thinning the crop, as it will do too much cleaning and destroy too many plants. The second kind of hoes of the hoe point or small bladed type are used for both thinning and for weeding and stirring the soil; as this leaves some unworked space between one tooth and another, the work is not thorough and will have to be repeated oftener than the first type. They are much in use for interculturing ragi fields sown broadcast or in very narrow rows.

In certain parts of the country the plough itself is used for interculture, ploughing being in furrows rather wide apart and also both lengthwise and across the field; a great amount of thinning takes place but the requisite stand is generally obtained, and the method is largely in use in fields of cotton sown broadcast, which is a crop requiring much space for the individual plants. Even in crops sown in rows, as in the case of jowar, a light plough is run between the rows close to one side of the row, with the object of earthing up the row and of holding rain-water close to the crop row, in addition to the weeding and soil stirring.

The interculturing hoes are very light implements and are easy on the bullocks; the bladed types are often used in sets of two or three for each yoke; even the hoe point type can be sometimes seen being used in a pair, both of them being handled by only one man. In the first type each hoe is held by a separate man, only one pair of bullocks being used.

The bladed hoes are made in different sizes suited to different crops according to the width of the rows, and are from 9" to 18" in length. In the case of crops sown or transplanted chessboard fashion these are worked both along and across the fields in between the rows. Where the rows are wider, say, 4', then two hoes of the required size will have to be worked in each stretch. These bladed hoes are remarkably efficient in their work, which is both thorough and quick.

Hoeing Irrigated Crops

All these bullock implements are used generally in the case of the dry crops and are seldom seen in irrigated crops where the fields are laid out into beds or ridges and furrows, which will be damaged by bullock hoeing and have to be redone after every hoeing. Except where irrigation is by flooding and in fairly level fields, these hoes cannot be used and only hand hoes are possible. In one method of sugarcane cultivation, *viz.*, the *cheni* variety as it is

practised in Mysore, much interculture with the bladed bullock implements is possible as in the case of the dry crops but this is an exception.

Wherever possible after every irrigation even in such irrigated fields or garden crops where fields are kept clean of weeds by hand weeding, a stirring of the surface by means of bullock hoes or hand tools is necessary in order to prevent the caking and crust formation in the soil and to preserve the moisture below ground.

A somewhat noteworthy kind of interculturing is carried out even in flooded rice fields in the heavy rainfall tracts of the Mysore malnad where the rice is sown in drills. The interculture takes place under water between the rows and great masses of weeds and surplus rice plants are uprooted and brought up by the hoes. Here too hoeing is repeated more than once. In ordinary rice cultivation, only hand weeding is carried out and the question of moisture conservation does not arise; it is purely one of weed removal and thinning. In careful cultivation a hand weeding follows the last interculture by bullock hoes, which removes weeds from places which are too near to the plants or in corners which are not reached by the hoes. With this operation, work in the field prior to the harvest, barring regular irrigation, watching and the like, comes to a close and the farmer has only to prepare himself for the harvest.

CHAPTER X

MANURES AND MANURING

FARM-YARD MANURE AND OTHER BULKY MANURES

IN a comprehensive sense, manures may be said to be the materials which are added to the soil, in order to increase very materially the yield of the crops that may be cultivated on it and to maintain its fertility at a high level from year to year. Manures may produce this effect by (1) making direct additions to the various plant foods, *viz.,* nitrogen, phosphoric acid, potash and lime mainly and any of "trace" or minor elements in which the soil may be lacking; (2) improving or correcting its physical conditions or defects and thereby enabling it to make the best use of the plant foods in the soil and those supplied in the shape of manure; (3) increasing its moisture-holding capacity; and (4) furnishing the organic matter necessary for bacterial activity and helping thereby in the maintenance of the level of the fertility. The older and well-known manurial materials, such as the excreta of farm animals, general waste materials of plant and animal origin, domestic and farm refuse and even human excreta owe their manurial or crop-increasing power to a combination of all these functions and they have been the main, if not the sole, manures known and used from the earliest times.

THE MINERAL THEORY OF LIEBIG

It is only within the last two centuries, dating as a matter of fact from the work of the famous German chemist Justus von Liebig when the concept of plant food elements arose and became generally accepted that the range of substances which can be used as manures became greatly expanded and a large number of new materials began to be used as manures. It was only from then also that the real reason why and how manures exerted their beneficial action and to what particular element or elements the action was due began to be understood. The subject of plant food elements in the soil has to some extent been already dealt with in the Chapters on "Soils", but it will be useful to refer to some aspects of the work of Liebig in this connection. Liebig taught that crops will have to be supplied in the form of manure, with the mineral elements of which they are composed, that is to say, whatever may be found to be contained in the ash of the crop plants obtained by burning the tissues, *viz.,* root, stems, leaves, seeds, etc., and that they could obtain everything else from the air and water. These mineral elements or "plant foods" according to him were only phosphoric acid, potash and lime, as all the other elements are abundantly supplied by all soils. A noteworthy omision is of course nitrogen. Though the great importance of nitrogen was fully recognised, Liebig believed that plants derived

it from the atmosphere just as carbon was obtained from the carbonic acid in the air. That plants can thus depend only on the nitrogen of the atmosphere for their plant food requirements was strongly controverted especially in England, where the opposite view was held, *viz.*, that plants can take up nitrogen only in the shape of manure from the soil and that they cannot take it up from the nitrogen of the atmosphere. It was the work associated with the names of Hellriegel and Wilfarth later on, on the property of leguminous plants, which established the truth of *both* views, *viz.*, that the plants belonging to the leguminous order have the power of drawing upon the nitrogen of the air for their needs but that plants of the non-leguminous orders do not possess this property and will therefore have to be given their nitrogen requirement in the shape of manures. The great service rendered by Liebig was—although his views about nitrogen supply to plants were only partially true—that the subject of manuring was placed on a scientific footing, questions of what manure to give, how much, and in what stage and so on, all being linked up with the composition and intake by crops of these plant food elements.

Another aspect of his work also worth noting is the predominant place which came to be occupied by the so-called 'mineral' (as distinguished from the organic manures) and the idea that as long as these plant foods (including nitrogen) are supplied by manures the requirements of crop increase were fully met, no matter whether they were in organic or inorganic forms. This led to a kind of logical development in what is known as Prout's system of farming, in which crops are raised with the help of these inorganic manures alone, and the need for keeping cattle for the sake of manure is altogether dispensed with. In the main, it may be said that this aspect of manuring holds the field even today, although not in the same extreme form which Prout's system implies. The need for organic matter in some form of cattle manure especially is however beginning to be stressed strongly in recent years and, curiously enough, is in its turn being carried to a like extreme, as Prout's system did with regard to mineral manures to the exclusion of organic manure. The subject is further dealt with separately later on (see Chapter XII).

The Role of the Main Plant Foods

The value and use of manures are judged according to their content of one or more of the three main plant foods, nitrogen, phosphoric acid and potash, their percentage therein and also the extent of their quickness of action or "availability" to the crop. In the selection of manures for the different crops moreover, the role of each of these plant foods in the nutrition of plants is also taken into account. The particular manner in which each of these plant foods benefits the crop may now be briefly described.

(*a*) *Nitrogen.*—Nitrogen is chiefly concerned in the vegetative development of the plant and is very striking and quick in its result. The manured plant puts on a dark green appearance, both leaves and stems grow markedly in size, tillering and branching are increased and altogether a somewhat luxuriant growth is produced. Heavy nitrogenous manuring may lead to a retardation of the flowering and an over-luxuriant growth may interfere with the yield of grain. Normally, however, especially in India, nitrogen leads to increased production, practically in every case and in the grain crops to increased protein content also. Judged by response in the shape of increased produce whether in grains, sugarcane or other crops nitrogen is the most important plant food in India and the others come a long way behind, even if they do produce an increased crop. Over-manuring with nitrogen may predispose the crop sometimes to fungus and other diseases. All nitrogenous compounds have to be converted into nitrates in the soil before they can be taken up by plants and nitrates form therefore the quickest acting among manures. As this change has to take place in the soil the conditions therein have to be favourable for such change or nitrification. The rice crop however can take up nitrogen in the form of ammonia and is therefore an exception.

(*b*) *Phosphoric Acid.*—Phosphoric acid is chiefly concerned in grain formation and in the reproductive phase of the plant generally. Over-luxuriance may be reduced or corrected and the flowering stage may be hastened by phosphate manuring. Better root development and a sturdier growth are often the result of such manuring. The proportion of grain to straw is increased and in certain cases the 'quality' of the produce. In contrast with nitrogenous manuring earliness is a rather general result of phosphate manuring. Phosphoric acid manuring has been both useful and necessary in the case of tubers and root crops like potatoes, sugar-beets, turnips, radishes and the like.

(*c*) *Potash.*—Potash is the plant food mainly concerned with the assimilation and the formation of starch and sugar, the primary functions of plant life. The absence or shortage in the supply will seriously affect growth, but it happens fortunately that most soils are sufficiently well supplied in potash against such a condition. Want of adequate and ample supplies in available condition will however lead to abnormalities in growth; this has been found to be the case in sugar-beets and mulberry, where leaves become crinkled and twisted on this account, which is a condition capable of being remedied by the application of potash manures. Usually however the supplies are abundant and in India especially it is a very noteworthy and even extraordinary fact that no response in the shape of increased crop is seen with potash manuring even in the case of a crop like sugarcane.

Need for Complete Manure

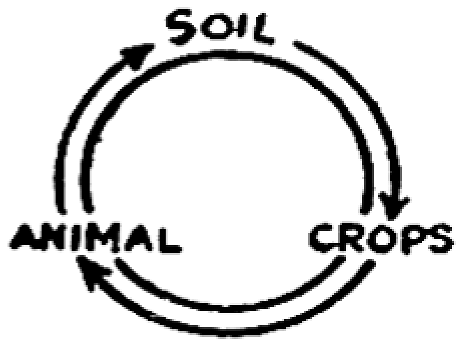
Though each of these plant foods has a special role as above, all are required in adequate quantities and proper proportions, for normal growth and development. In the total absence of one or other of these, plants will not make any growth at all and all three are required to be supplied. Soils contain more or less of all the plant foods and a total absence of one or other of them seldom or never occurs. The problem then is to find out in respect of which particular plant food it has to be enriched or supplemented through manuring. A safe rule is to give a complete manure, in which the largest proportion will be that particular plant food in which the soil is poor or to which it is likely or known to respond. The reasons are the following: (1) The response to manuring is not merely in increasing the quantity of produce, although this is the main, if not the sole, object of manuring. Manuring will and is known to affect the "quality" of the produce, such as the composition of grains, fibre quality in cotton, sweetness in fruits, etc., and even the vitamin content (as it is claimed sometimes). (2) The strength of the vegetative parts of the plants and their ability to withstand disease are also affected by the lack of one or other of the plant foods and all of them have therefore to be supplied. (3) The quantities of the different plant foods taken up by plants depend to a large extent upon and is much influenced by, the proportions in which they are given; for example, phosphoric acid is taken up better in the presence of potash and *vice versa.* A large proportion of one plant food leads to a proportionately large intake of another or others, so that an one-sided manure will soon exhaust the soil of other plant foods, with perhaps serious consequences of a permanent nature. This is the result which is feared may happen by a large one-sided nitrogenous manuring which one is tempted to give on account of the striking response, and which should therefore be corrected in time by supplying the other plant foods as well, although the response to this addition may not show itself. A complete manure in which the required plant food largely predominates is therefore safe, whatever the indication may be as judged by the increased weight of the produce.

Kinds of Manures

The various manures are classified in different ways, according to the feature of the manure which is intended to be stressed. They are classified, for example, as bulky and concentrated manures, as slow- and quick-acting manures, as one-sided and composite or complete manures, as organic and inorganic or mineral manures, as natural and artificial manures, manures of vegetable, animal and mineral origin or as nitrogenous, phosphatic and potash manures.

FARM-YARD MANURE

The excreta of animals, both solid and liquid, form the most natural manure, fitting into a natural cycle of life, which may be represented thus :



The fertility of the soil is taken up by the crop which grows on it, which in its turn enters into the body of animals of all kinds which feed upon the crops and whose excreta therefore return to the soil what originally belonged to and came from it. Farm-yard manure is a bulky manure, containing only very small percentages of the plant foods in proportion to its bulk. Most of it is in organic combination; and it is an 'organic' manure. It is a general or complete manure, containing all the plant foods, albeit in small quantities. It is slow-acting, its effect is felt for more than one season and the residual effect is considerable.

Composition.—Farm-yard manure (also called cattle manure) is strictly speaking the solid and liquid excreta of the cattle kept on the farm, *i.e.,* the dung and the urine, but in practice a lot of farm wastes especially the straw derived from the waste fodder and from the litter or bedding if such is provided, is mixed with it and forms an addition; on the other hand, a good portion of the plant food contained in the urine is lost in the method of collection and storage. The manure is of course very moist and contains a large, but somewhat varying, quantity of water in the condition in which it is carted to the manure heap or to the field.

The composition of the solid and liquid excreta of cattle (bovine) in respect of their plant food content is somewhat as follows :—

	Per cent.			
	Moisture	Nitrogen	Phosphoric aicd	Potash
Solid excreta or dung of cattle (average)	80	·34	1·7	·15
Urine ..	90	·80	·01 (or trace)	1·4
Fresh manure (both dung and urine)	85	·53	·53	·36

Of the total quantity of plant foods in the excreta, the urine contains the major part of the nitrogen, almost the whole of the potash and

a very small portion of the phosphoric acid. The urine must therefore be considered the more valuable part of the manure.

Excreta of Other Farm Animals

The composition of the excreta of the different kinds of animals kept on the farm generally other than oxen, differ to some extent from one another thus :—

			Moisture	N	P_2O_5	K_2O
Horse	Dung	..	76	·50	·35	·30
	Urine	..	90	1·50	·0	1·3
Sheep	Dung	..	53	·75	·60	·30
	Urine	..	86	1·50	·01	1·8
Pigs	Dung	..	80	·60	·45	·5
	Urine	..	98	·40	·13	1·5
Poultry Mixed		..	56	1·6	1·5	8·5

Horse Manure.—Horse manure differs from the excreta of oxen, in the quickness with which it ferments and heats up. Heaps of horse manure always show signs of such heating up, by the many 'fire-fanged' patches, mostly in the interior. For this reason horse manure has to be kept a long time, till it can no longer deveolp so much heat, or becomes spent out, so to speak, and only old manures should be used. On account of this heating property horse manure is used much in hot beds and for forcing germination (though this is not often seen in India). The nitrogenous compounds in horse urine and dung are also different being largely hippuric acid, rather than urea as in the case of other animals.

Sheep Manure and Sheep Penning.—Sheep (or goat) manure is characterised by its comparative dryness and the fine condition to which the coarser portions of its feed have been reduced in the digestive process; the pellets of manure can well be powdered by mere rubbing into a fine powdery manure. One reason for the dry powdery condition is that sheep and goats drink comparatively small quantities of water. The manure as it is gathered is only in the form of dry pellets and seldom mixed with the urine as in the case of other animals. To get the full benefit from the excreta of sheep, the practice of sheep folding on the land to be manured is adopted, so that the whole of the urine and solid excreta may get into the soil as manure. With the same object it is also customary to disturb the sheep many times in the course of the night, as they urinate every time they wake up, which means more manure on the land.

Sheep penning or folding is done in one of two ways, either by penning the sheep on land well ploughed and brought into good tilth preparatory to sowing or, by allowing them to graze down stubble or crops specially grown as sheep feed. The last one is however not practised in India but is very common in Europe and America where fodder crops like turnips, clovers, etc., are specially grown and are

then fed off the field by sheep. The latter is a form of sheep husbandry, where the object is to convert the crop into marketble mutton, while the former is only a form of manuring, as far as the owner of the field is concerned. For fields situated in far-off places to which the carting of manure may be difficult, manuring by sheep folding is very suitable. It has been computed that a flock of 1,000 sheep will add in the shape of manure in one night's folding 8·8 lb. of nitrogen per 1,000 sq. yd. of ground or about 40 lb. per acre. Valuable crops like tobacco are systematically manured with sheep folding in parts of the Mysore State.

Pig Manure.—The manure of pigs is a comparatively less valuable manure than that from other farm animals, as these animals utilise practically the whole of the plant food in the feed in building up their tissues and the manure voided is poorer to that extent. The digestive system of the pig cannot make use of course cellulose material, and its feed therefore consists of starchy roots or mashes or grains (where pigs are kept and fed); on this account its manure is small in quantity, well ground up and subject to rapid decay. As pigs are kept in India only by wandering swineherds and act more or less as scavengers, the manure is seldom worth considering.

Poultry Manure.—The manure from poultry is a semi-solid messy stuff, as the solid and liquid excreta are voided together and not separately as in the case of the other animals. If it can be collected properly it is a valuable manure, but the quantity on the ordinary farms of this country is usually insignificant. Great quantities may however accumulate under special conditions and the valuable guano deposits in various parts of the world owe their origin to the excreta and dead remains of myriads of birds which breed in those regions. The manure from bats is different (the bat is of course not a bird) and in a small way in many caves and the dark interiors of many large temples much bat manure (solid excreta) accumulates and the quantities are large enough to make it worth while collecting and selling; the manure is considered a very valuable manure and is much fancied in the cultivation of water-melons in South India.

Quality or Composition of Farm-yard Manure

What is called farm-yard manure consists generally of the manure from oxen, *i.e.,* the bullocks, cows, buffaloes and young stock of these animals; admixture with the manure from other kinds of livestock is very little or none at all. Taking only the excreta (both solid and liquid) of such animals into consideration, the quality of the manure will depend upon (1) the feed given to the animals; (2) the age of the animal; (3) the purpose for which the animals are used. By 'quality' is meant, it may be explained, the nitrogen content of the manure, this being the most valuable part of the manure. The richer the food, *i.e.,* the richer it is in the proteids, the better and more valuable is the manure, in other words the higher the nitrogen

content. Cattle subsisting merely on coarse straw or similar fodder can yield only poor manure, whereas cattle receiving rich concentrated feeds like oilcakes, gram, cottonseed, etc., will yield valuable manure. As regards age as a factor in the quality of manure, it should be noted that an adult working bullock will void nearly the whole of the nitrogen of the feed, as it has ceased to make growth and as its requirement is mainly energy for work with a very small amount of proteids for the repair of tissue. On the other hand, a young growing animal or one which is yielding milk or is pregnant with calf, will utilise a good portion of the nitrogen for the building up of tissue and the production of milk, and will void only the remainder of the nitrogen in the excreta, which will therefore not be so rich as in the case of adult working animals.

STORAGE AS AFFECTING QUALITY

(a) *Collection*

Whatever the quality of the manure may be as it is voided, it is subject to a great deal of deterioration through loss of valuable plant foods in the methods of collection and storage. Much of this loss is inevitable and the methods should be such as to minimise it as far as possible. The chief loss in the collection is due to the fact that the urine is not collected in full and added to the dung. Most of it is lost by soaking into the mud floor of the stall or flows away for lack of proper drains and collecting arrangement.

This kind of loss in collection may be avoided or reduced by (1) having a watertight floor for the stall provided by concrete or stone or even well-tamped hard gravel and given the correct slope; (2) having a good drain into which both the urine and the washings may flow and which will empty into a good receptacle such as a masonry or cement-lined cistern, a large barrel, drum or even a mud pot, from which the contents may be removed and added to the manure heap or pit. If the floor is made of stone slabs or of cement concrete, then it will have to be roughened by means of regular grooves (usually herringbone style) or simply by the stone-mason's chisel; otherwise the floor may become slippery and the animals may hurt themselves when lying down or getting up. Such roughening will have to be repeated whenever the floor wears smooth.

In the alternative or as an additional means, some absorbent material such as straw, leaves or other waste material may be used as bedding under the feet of the cattle; this will absorb much of the urine and may be removed daily or at frequent intervals and added to the manure heap. Even ordinary dry earth may be used instead or, as is the practice in certain tracts, cattle dung partially dried and broken into coarse powder. Both are excellent as absorbents and may be renewed every day, the old or used up material being added to the manure. It is obvious that all these absorbent materials also add directly both to the quality and to the quantity of the manure.

In addition to the loss in this way, the urine suffers loss in quality which is rather more difficult if not almost impossible to prevent. The nitrogen in the fresh urine is present in the form of urea, which begins to be converted into ammonium carbonate by bacterial action almost from the moment it is voided, from which ammonia escapes into the air, resulting in serious loss of nitrogen. The sprinkling of very dilute sulphuric acid, a little gypsum or superphosphate of lime on the floor of the stalls will both prevent the loss by fixing the ammonia as ammonium sulphate, and this method is sometimes attempted; but in practice, it is not of much value as the quantities required for efficient absorption are found too large for practical use and in any case can hardly be thought of for farmers in this country.

(*b*) *Loss in Storage*

The whole of the solid excreta is generally removed without losing any and put into the manure pit together with the waste straw, bedding material and sweepings, to which are added the urine and washings if separately collected. Each day's manure is likewise collected and added to it, and this goes on from day to day during the period from the beginning of one crop season and the next, which is the total length of time that the manure has to remain in storage.

(1) *By Oxidation.*—Changes go on during this period, both chemical and bacterial, which also cause much loss of plant food. This change is one of slow oxidation or fermentation, during which part of the cellulose material in the straw and the undigested portions in the dung are broken down. The process is incidentally one of humus formation, and cellulose decomposition results in a gradual reduction of the carbon by oxidation. The ratio of the carbon to the nitrogen rapidly goes down and may not amount to more than 10 or 15, as against the initial 30 or thereabouts. The ratio is indeed a measure of the extent of the decomposition or humification. The same oxidation in the case of the bacterial change results in the formation of ammonia and its loss into the air as a gas. If the oxidation is allowed to go on freely, such as by heaping the manure loosely, the loss of dry matter may go up to even 50%.

(2) *By Heat.*—Both these changes are hastened or helped by the heat which develops in the fermenting heap due to the oxidation and this is very considerable, as can be easily realised if one thrusts his hand deep into such a heap. The heat also dries up the manure and may even lead to a burning up of some portion which may become 'fire-fanged'. As however the manure has to become broken down to some extent so that it may be at least partially converted into humus and the coarse straw and other material to rot and as the changes cannot in any case be prevented, the loss by this process has only to be minimised as much as possible.

It may be added that a slight *increase* of nitrogen may also take place during storage as the result of the fixation of atmospheric

nitrogen by free-living bacteria, but this is very little and not worth taking into account.

The steps that can be taken to minimise this loss are the following: (1) keeping the manure well pressed and tamped, thereby excluding the free passage of air or oxygen; (2) the addition of water to keep down the temperature and the loss by driage and to help in excluding the air further; (3) the addition of absorbent material like red earth, tank silt or good dry loam at frequent intervals, so that the latter are laid in alternate layers with the manure and the heap is well covered with a thick layer of earth finally; (4) by having two or three small storage pits rather than one large one, so that the manure may not lie uncovered for too long a time. The way in which these devices help in preventing the loss is obviously enough and needs no going into further.

(3) *By Leaching out of Soluble Material.*—The next important loss in storage comes from the loss of soluble material, mainly the salts of potash, through seepage, exposure to rain and the flow or collection of water in the pit. Such loss should be prevented by erecting a thatch or roof over the pit, and further by putting a low bund all round the rim of the pit for keeping out surface flow. When finally removing the manure from the pit and emptying it, a layer of the earth from the bottom of the pit should also be taken out as that will contain much of the soluble material that seeped out of the manure.

Some Special Methods of Manure Storage

(*a*) *The "Box System".*—There are some methods of manure collection peculiar to certain countries or tracts which are designed for efficient conservation of manure and which may be referred to here. In one called the 'box system', which is prevalent in Great Britain, the manure and the straw used for bedding are not removed daily at all and the animals are stalled over their own excreta to which daily additions are made of bedding straw. The manure becomes tightly packed by the trampling of the animals and both solid and liquid accumulate without any being lost. The floor or bottom of the stall is below ground level and when the manure accumulates and comes up to the ground level, it is removed in the usual way and carted to the field or manure heap or pit.

(*b*) *The "Malnad" System.*—A very similar system prevails in the Mysore malnad, where, instead of straw, daily additions of green leaves from the forests are made, or hay cut and stored for the purpose is used by itself or in addition. This manure should be richer than that made in the British box system, on account of the green leaves used as litter or bedding; the animals however suffer great discomfort owing to a plague of flies and the wetness of the stall, especially in the rains.

(*c*) *The "French" System.*—In a third system the manure after every day's collection is heaped up in the shape of a square pile,

over a large covered cistern or cellar and the urine and washings are separately collected and poured onto the heap; the liquid manure drains through the heap down into the cistern or cellar and from this it is pumped back again onto the heap by a small chain pump. The contents of the cistern are removed in barrels when required and applied to crops or pastures, or pumped directly onto pastures. The method may be seen largely in the Channel Islands and among the French peasants.

Quantity of Farm-yard Manure

The quantity of manure varies according to the liveweight of the animals and the amount of feed consumed. A cow or an ox voids about 100 lb. of dung and urine per day (total dry matter 20 lb.) according to European figures. Conditions are quite different in India both in regard to the size of the animals and the kind and quantity of feed given and about 45 lb. per cow and 60 lb. per buffalo (dry matter about 7 lb. and 10 lb. respectively) is to be reckoned as the quantity voided by these animals (according to C. N. Acharya). This is made up of 30 lb. of dung and 15 lb. of urine per cow and 40 lb. of dung and 20 lb. of urine per buffalo, both fresh weights; a lb. or two may be added to this quantity in the shape of waste bedding or litter and the total theoretical quantity that should be available from any particular number kept can be readily calculated. In practice, however, considerably more waste fodder (depending upon the kind of dry fodder given), stall sweepings and household wastes all go into the manure pit, not to mention extraneous matter, like leaves, earth, etc., brought in and ashes from the household, which are all put in as additional matter; on the other hand the collection and storage leave much to be desired and act in the reverse direction. As a rough figure, therefore, and one generally obtaining in practice, only about 3 tons may be taken as the quantity from a pair of oxen on the farm as against the 16 tons per head of stock on British farms reported by McConnel. Even this will vary with the nature of the cultivation in the country, which usually influences the extent of grazing available and therefore of the quantity which is left on the grazing land.

Augmenting the Quantity

The quantity of manure may be increased and should wherever possible be so augmented, in the following ways: (1) collection and addition of dry leaves in the season; (2) and likewise of green leaves and loppings; (3) carting of tank silt, red earth, and jungle soil whenever possible; (4) collection of the solid excreta from the grazing areas and adding it to the manure; (5) provision of some amount of litter or bedding straw or other materials like dry earth, jungle hay, etc.; (6) the careful husbanding of all household wastes, both vegetable and animal, and kitchen ashes and adding them to the manure. All these contain appreciable quantities of plant

foods, while many will add to the organic matter itself. It may be possible to increase the manure supply very materially by these means.

Composition

The chemical composition of ordinary cattle manure is very variable as the following analysis will show :—

	Description	Moisture	Loss on Ignition	N	P_2O_5	K_2O	CaO	Insoluble Residue (Sand)
	From—							
1	Hassan (Mysore)	17·27	27·79	1·06	·54	·46	1·07	47·2
2	do ..	16·70	17·8	·64	·30	·45	·65	58·5
3	Bangalore ..	5·8	33·2	·77	..	·41	1·35	51·0
4	Europe ..	20·0	..	1·55	·90	1·44	..	..
5	British ..	75·0	81	·50	·26	·63	·70	..

Residual Effect

Farm-yard manure is a complete manure, supplying all the three plant foods; it is a bulky manure, as the very small percentages of the plant foods show; it supplies much organic matter to the soil. The plant foods are mostly in organic combination and are only slowly available in the soil, with considerable residual effect. The residual effect is very material and in British agricultural practice, a definite part of the fertilising value of the feeds consumed by live-stock on the farm is given credit for in the second year following the feed, and a certain portion, but very small, is allowed even in the subsequent year. Where tenancy is being changed, an outgoing tenant is given compensation for the residual or unused effect of the manure, based on the value of the feeds consumed by the live-stock. Thus a total of about 2½ years is allowed for the full utilisation or exhaustion of the manurial effect and half the value of the year of application is allowed for the following year, and ¼ is allowed for the next year.

Composts and Artificial Farm-yard Manure

The value of farm-yard manure does not depend upon its content of the three plant foods alone. One of its most important features is its organic matter content, its physical condition and the fact that it has passed through the digestive tract of cattle and is charged with the peculiar bacterial flora. Well-made cattle manure in a fit condition for application is almost waxy in consistency, with most of the fibrous and coarse matter in the shape of straw and other rubbish completely broken down. Such a consistency improves the physical condition of soil, increases its water-holding capacity and enriches the soil in easily available plant food. The rotting of the straw and other coarse material is very important in India on account of the pest of white ants which attack them in their undecomposed state.

Closely connected with this aspect of farm-yard manure is the process of making composts. This process consists in converting

Grove of *Pongamia glabra* trees; such groves are specially raised and maintained in certain parts of Mysore, for the sake of the leaves to be used as green manure on rice fields.

Photo by Author

The French system of storing cattle manure. Note the square piles of manure and the liquid manure pump by the side, for pumping up the drainings from the cistern below the pile—View at the School of Agriculture, Grignon, France.

Photo by Author

coarse vegetable debris or straw into something similar in physical condition to farm-yard manure, *i.e.*, into a material fit for application to the soil as manure. The woody structure is broken down and the material made homogeneous and powdery, and converted into such condition as the straw or other coarse fodder would be in, if they had passed through the digestive system of the animal as a feed. Changes are brought about by chemical action induced by bacteria, which are helped largely by the addition of varying quantities of farm-yard manure itself to the material. In fact in the ordinary manure pits which form the dumping ground for all kinds of refuse in addition to cattle manure, it is a kind of composting which takes place, with the difference that the materials other than cattle dung do not bulk so largely as the cattle dung, whereas the reverse is the case in compost making proper. Indeed in compost making cattle dung may be reduced to a minimum, almost to nothing, except the very trifling quantity which may be required to induce the cellulose breaking bacterial action. The dung for this purpose is added in the shape of a thin slurry in water. A certain amount of nitrogenous matter furnished either by ammonium salts or green vegetable matter like green leaves together with some phosphates and potash salts are all added with a view to hasten and increase the action of the cellulose destroying bacteria and the decay of the coarse material. The necessary moisture and aeration are also provided by the addition of water and the frequent turning over of the heap at intervals of a few weeks.

Compost from Sugarcane Trash.—The conversion of sugarcane trash (dry leaves) into compost described below may be taken as an illustration of the method and generally applicable to materials of a similar kind.

The cane trash is put up in heaps mixed with some green material like grass or weeds. For this purpose the best way is to sandwich the green stuff between thick layers of the trash, after moistening the former with a slurry made by stirring up cow dung in water in the proportion of 7 parts of fresh cow dung for every 100 parts by weight of the green stuff, along with three parts of wood ashes and five parts of earth. It may be also necessary to add both lime and bonemeal to the heap at the rate of half part unburnt lime and five parts of bonemeal per 100 parts of green material. Heaps 8′ in width and 3′ in height and with length depending upon the quantity of trash available are made, the bottom consisting of a layer $4\frac{1}{2}''$ thick, of cane trash alternating with $1\frac{1}{2}''$ layer of green stuff thereafter. After a few days the heap is broken up and remade with a further addition of green material. Where green material cannot be had, some sannhemp seeds may be sown on the heap; the growth of these plants after 3 weeks will furnish sufficient material for addition at the next breaking and remaking of the heap.

The process called "ADCO" is a well-controlled process of composting, in which straw is reduced into manure without any farm-yard

manure, as such, which is therefore dispensed with; bacterial action is induced with starter cultures of cellulose breaking bacteria and small additions are made of sulphate of ammonia, phosphates and potash salts in order to favour rapid bacterial action. The "ADCO" mixture is put out by the company of that name and is reported to contain about 9% nitrogen and 6·7% P_2O_5, the success depending much upon the correct ratio of nitrogen to the carbon in the cellulose material. It takes about 3 months for the materials to decompose into a form resembling cattle manure to which indeed the name 'artificial cattle manure' is applied.

Compost-making which is adopted as a method of advantageous disposal of town wastes, night soil, sewage, etc., is described separately.

Green Manures and Manuring

Green manuring is the practice of applying as manure large quantities of green material such as the leaves and twigs of various plants, trees and shrubs or crops themselves specially cultivated for the purpose. These are either cut and brought from outside or grown in the field in which it is intended to be ploughed in as manure. In the first case the whole of the plant foods, nitrogen, phosphoric acid and potash contained in the material brought and ploughed in is an addition by way of manure to the soil. In the second case there is no addition of these plant foods, except when the green manure crop grown is a leguminous crop and in this case the whole or part of the nitrogen is a direct addition, because it had been derived from the nitrogen of the atmosphere and not from the soil. Even in respect of the mineral plant foods, phosphoric acid and potash, in one sense they can also be looked upon as an addition, because they have been drawn largely from the lower layers of the soil and become a gain to the top layers in which the green manure is ploughed in. In both cases, the large and important addition is the great bulk of organic matter, whose importance to the soil has already been explained. In improving the physical condition of the soil, in increasing its moisture-holding capacity, and making it more retentive of moisture, in promoting bacterial action by furnishing the necessary carbonaceous food material, and in increasing the yield of crops as their combined effect, the value of the organic matter is very great.

Green Manure in Rice Cultivation.—Green manuring (for the ordinary field crops) is of importance only in the case of the puddle cultivation of rice; to a smaller extent it is adopted in the case of a few irrigated crops like sugarcane and potatoes and to a still smaller almost negligible extent in the case of dry crops. In the case of rice cultivation the green manure is applied either in the fresh condition or within a few days of cutting, where green material is cut and carted from elsewhere, and immediately after cutting or without any cutting at all where the green manure is grown in the field itself. It is only in rare instances that the material is stocked

until it is quite dry and then ploughed in. In puddle cultivation the material is trampled in the soft mud and allowed to rot; the action is favoured by the abundant moisture present and there is no difficulty in this respect. Where the material is used in garden or irrigated crops also this condition of abundant moisture is fully satisfied. Where it is used for dry crops (as is done in rare instances) the supply of moisture is not always plentiful and is, if anything, largely wanting and the decay and disintegration of the material is therefore very slow. Both moisture and aeration are necessary for the decomposition and in the case of dry crops this may be delayed too long for the sowing of the main crop in time.

Crops Grown for Green Manure.—The crops grown for green manure purposes to be ploughed under in the field where they are grown comprise the following, *viz.*, sannhemp (*Crotolaria juncea*), daincha (*Sesbania aculeata*), wild indigo (*Tephrosia purpurea*) and the various pulses like cowpeas (*Vigna catiang*), greengram (*Phaseolus radiatus*), blackgram (*Phaseolus mungo*), horsegram (*Dolichos biflorus*), pillipesara (*Phaseolus aconitifolius*). The seeds are sown thick in the field after a rough preparation with one or two ploughings in the early rains of April or with a light irrigation if possible. The sowing should be so timed that at least 2 months' growth will be possible before ploughing the crop in. In puddle cultivation, the field with the standing crop of green manure on it is heavily flooded and the ploughing started. If the growth is not very heavy and tall the material is ploughed under easily; but where growth is heavy and tall as in the case of daincha and sannhemp, the crop is cut down, laid in narrow rows or spread evenly and then ploughed under, so that in both cases the material becomes buried and covered over. For this purpose a mouldboard plough is more serviceable than an ordinary country plough. The burying under is also helped by both the ploughman and bullocks trampling the stuff into the mud as they walk along.

If the crops were grown under some amount of irrigation and if the sannhemp crop was not defoliated by the sannhemp leaf-eating caterpillars, then very heavy growths of these crops are possible.

Plant Foods Added by Green Manures.—All the above-mentioned crops are legumes and the total nitrogen contained in the tissues is nearly all taken from the atmosphere and is therefore a direct addition to the soil. The nitrogen so added by these crops and the mineral plant foods contained in them (which as already explained may also be looked upon as an addition) can be judged from the following figures of analysis:—

		Percentage of			
Crop		Nitrogen	P_2O_5	K_2O	CaO
Sannhemp	..	·75	·12	·51	·39
Cowpea	..	·71	·15	·58	·64
Greengram	..	·72	·18	·57	·76
Blackgram	..	·85	·18	·53	·74
Avare	..	·75	..	·56	·67

It is possible to materially increase the nitrogen content, if these green manure crops are manured with phosphates and potash manure; in that case the crop will be stimulated to assimilate more nitrogen from the air by an increased formation of the root nodules and the bacteria concerned. Moreover for the subsequent crop of rice, the addition of phosphates and potash may be dispensed with, these having been given already to the green manure crop to be ploughed in. This is in fact a method of phosphate and potash manuring for rice, which secure two objects at the same time (see also pages 78, 79).

In recent experiments reported from Coimbatore, the fixation of atmospheric nitrogen amounted for a single season to nearly 120 lb. per acre with daincha, 80 lb. to 90 lb. with pillipesara, about the same quantity with sannhemp, and 50 lb. to 80 lb. with cowpeas.

Quantities of Green Material.—Very heavy yields of green material are possible with some of the green manure crops, under partial irrigation the most notable being sannhemp, of which from 20,000 lb. to 30,000 lb. are reported per acre; daincha may yield up to 20,000 lb. while the others up to 8,000 lb. or 10,000 lb. Among the low-growing crops the pillipesara is a heavy yielder giving up to 15,000 lb. The wild indigo yields the lowest quantity, and may not go over 3,000 lb. or 4,000 lb. All the pulse crops give very sappy and easily decomposable stuff, but their yield of green material is low, except in the case of cowpeas. The daincha becomes rather woody; the sannhemp becomes too tall and close-grown and will need cutting up into shorter lengths to be ploughed in with ease. Among the pulses practically all of them except tuver (*Cajanus indicus*) are grown for green manure.

Green Manures in Irrigated Garden Cultivation.—In the case of the irrigated garden crops like sugarcane or potatoes, green manuring can be given likewise by growing one of the legumes as in the case of rice and then mixing it suitably with the soil. This is usually done by chopping up the plants and then ploughing or digging, in order to mix the material with the soil. Where heavy mouldboard ploughs are used as in sugarcane cultivation, the crop may be ploughed in as such, with a sort of chain or log attachment to the plough which will help in laying the crop flat and push it into the furrows. It will be found, however, more satisfactory on the whole, to cut up the green growth into pieces and scatter it in the field. Sometimes men are set to walk through the field slashing the crop right and left with a sharp sickle, and this leaves only a short stubble or stem remaining, which is very easy to manage with a plough. The green material is left to decompose on the field for at least 2 weeks, so that it then mixes with the soil well and can be further worked in, with the later ploughings. Such addition of green manure is preparatory to the crop and is adapted for both sugarcane and for potatoes, as it is in the case of rice in puddle cultivation.

In the alternative especially when it is believed that organic manure has not been adequate, the sugarcane crop can be given green manuring in a different way. For this purpose sannhemp is sown thinly in the sugarcane beds between the furrows, and in fact in all the space not covered by the cane, and allowed to grow for some 4 to 6 weeks. It is then pulled out or cut down when the weeding is being done and mixed with the soil. It cannot be left longer to grow, as it may in that case smother the cane and interfere with its growth. Sugarcane is also given green manure by applying large quantities of honge (*Pongamia glabra*) leaves, in the furrows between the young crop and covering it up with the earth from the adjoining ridge. In all these cases decomposition takes place only in the moderately moist soil but not in puddle and under water as in the case of rice.

Green Manuring for Dry Crops.—The growing of a green manure crop and then ploughing it in before sowing has been tried for dry crops also. In Mysore trials were made with the dry land crop ragi (*Eleusine coracana*). The main object is to increase the organic matter content of the soils which are as a rule very deficient in this respect. In practice such manuring is rather difficult to manage; the green manure crop will have to be sown with the very first rains after the fields have been ploughed and got ready, and it will have to be ploughed in at least 2 weeks prior to the sowing of the ragi, so as to give it time to decompose to some extent. Sowing rains after this lapse of time may not always be favourable and as the sowing of the ragi crop at the proper time is of paramount importance, this kind of green manuring will militate against this paramount need. Moreover, within the short period allowed for the green manure crop and with rains usually not very certain or satisfactory, the quantity of green material obtained will be small. If the field had been ploughed immediately after the previous harvest and was fit to receive the green manure seeds in the very first rain, the conditions may be a little more favourable for the growth of the manure crop and it may be possible to plough it in, in time for the ragi sowing. Ordinarily, however, the practice cannot be adopted where the rains are precarious, as the requirements of the main crop are of overshadowing importance. Its advantage where it can be adopted is undoubted, especially on the soils concerned.

The Nature of the Decomposition.—The decomposition of the green manure in all except in puddle cultivation is very much like that of any nitrogenous organic matter. The carbonaceous material slowly oxidises into carbon dioxide, disintegrates the material and reduces its bulk. Nitrification takes place gradually and if the main crop is on the land or follows immediately, the nitrates are promptly used up as they are formed. This nitrification also begins and progresses rapidly almost as in the case of oilcakes. In the case of puddle rice cultivation however it has been found that there is no such nitrification, that nitrogen is in fact given off and escapes into

the air, that the organic carbon is slowly oxidised and that marsh gas is also given off, and that the carbon dioxide is utilised by green algæ growing on the surface of the water for its assimilation, carbon being utilised and oxygen given off. There are probably other gases, the result of imperfect oxidation, which are given off, such as even sulphuretted hydrogen and ammonia if one may judge from the smell which accompanies the rotting of sannhemp in the puddled field. The beneficial effect of the manure on rice crop is attributed to the aeration of the roots brought about by the oxygen evolved by the algæ and the greater capacity of the crop to take up plant food from the soil. It is rather difficult to reconcile this view with the great benefit derived by the crop and the increased yield and the general ideas regarding the plant food requirements of crops.

Fermented Green Manure.—In all the above cases the green manure is applied in the fresh condition or when they are not more than a week or two old after cutting. It has been suggested that a better practice will be to ferment the material first and then apply it to the field along with the drainings, somewhat on the analogy of applying indigo *seet,* and the spent or fermented indigo plants as manure. This method has been suggested in the case of sannhemp manure. When it decomposes this crop has been found to give off at one stage gases like sulphuretted hydrogen which are deleterious to the standing crop. Bacterial action is also delayed and the effect is very uneven, on account of insufficient moisture. If the manure should be fermented before application to the soil, then these gases escape into the air and the fermented manure becomes innocuous in that respect and also more quick-acting. A pre-fermentation is therefore suggested. From a practical point of view the method cannot obviously be thought of except on a very small scale. Moreover in the generality of cases the crop is sown or transplanted only after a certain length of time lapses after the manure is ploughed in, during which period these gases, if any, can freely escape into the air and render the manure innocuous. A system of composting sannhemp by first soaking it in water for a night and then taking out the material and heaping it with alternate layers of earth, has sometimes been recommended. The method is useful as a means of keeping the green manure over some months, prior to ploughing it in.

Some Popular Preferences.—Some green manures are popularly believed to benefit soils and crops in other ways also, besides adding to the plant food contents of the soil. Many like 'neem' (*Melia azhadirachta*) and 'yekka' (*Calotropis gigantea*) are specially esteemed for the correction of alkali in soils and are therefore much sought after for the improvement of alkaline soils. Others like 'honge' (*Pongamia glabra*) and 'neem' are believed to be able to keep insects and larvæ from the soil and thus to eliminate some crop pests. All of them improve the physical condition undoubtedly, and their action in reclaiming alkaline soils is probably due largely to this im-

provement and the consequent facility for better drainage. Direct neutralisation of the sodium carbonate in the soil also takes place during the decomposition of the green material in such soils. The repellent action against insect pests is also very probable as 'neem' leaves and indeed all parts of the plant contain a very bitter principle and as 'honge' roots and wood (and probably leaves) have been found to contain considerable rotenone.

Green Manures and Cover Crops.—Very often green manure crops like the various legumes and especially those with a creeping habit and capable of affording a quick growing leafy cover to the soil, are grown in plantations of various crops and are ploughed under or dug in at the proper time. Such cover cropping is also sometimes followed in field husbandry and generally precedes the main crop, at a time when the field would ordinarily otherwise lie fallow. This is more or less a catch crop, grown more for the sake of the produce than for manure or cover, both of which are only incidental. If conditions are favourable and the crop matures, then it is picked whether green or dry; if not, and if the sowing of the main crop is likely to be delayed then it is ploughed under as a green manure or as is more common, part is picked as green pods and what remains is used as manure.

In plantations, it is a purely manurial and cover crop; in addition to increasing the supply of organic matter and nitrogen, they serve to smother weeds which will spring up otherwise and usurp all bare patches. While the advantages are obvious from what has been said so far, it is well to balance against them at least one risk, which may prove serious where rainfall is poor or irrigation is not practised. This risk relates to the serious depletion of soil moisture by a growing crop. Reference has already been made to the extent of such depletion both in degree and depth by even a moderate crop (*vide pages* 68-70). In orchards and cocoanut plantations depending solely upon rainfall for instance, such a risk becomes really serious. In such cases the method cannot be adopted and recourse must be had to the usual direct methods of manuring with farm-yard or other manures.

Among the crops which can be grown for this purpose in plantations, especially rubber and to some extent of coffee and tea before the rows close up or in bare patches in older plantations are the following:—

Tephrosia candida	*Cassia tora*	*P. trilobus*
T. purpurea	*C. hirsuta*	*Canavallia ensiformus*
T. villosa	*Indigofera endacaphylla*	*Dolichos lablab*
Crotalaria juncea	*I. erecta*	*D. biflorus*
C. anagaroides	*Phaseolus plumerii*	*Vigna catiang*
C. striata	*P. lunatus*	

and several other species of all these plants. In the case of those crops in the list which yield edible pods like *Dolichos lablab, Vigna*

catiang and others, they should be cut down before the pods form, lest a plague of monkeys should descend upon the crop and transfer their attentions later to the plantation crop itself.

Stage at which to Cut Down Green Manure Crop.—Plans grown for green manure have to be cut about the time (that is, when one has a choice in the matter) when they begin to flower. At this stage the uptake of plant food both from the soil and from the air as well as the assimilation of carbon and the development of organic matter reaches practically the maximum. Moreover at this stage the plants are in a comparatively tender and succulent condition, and if left longer may become woody or fibrous and less easy of decomposition. It will be advisable therefore not to overstep this limit. There may however be no choice left in the matter and it may be necessary to cut it earlier in the interests of the sowing or planting of the main crop; in that case the quantity of the green material will be much less although it will be more tender and will decompose quicker. Crops differ materially in the quantity of green material which they will yield at this stage of flowering. Among the crops dealt with, it has been found that sannhemp if sown thickly will yield the largest weight within the shortest time and the general preference for this crop for green manuring purposes is quite justified.

Green Manure as Cattle Feed.—There is another important aspect of some green manure crops, *viz.,* their suitability as cattle feed, which though generally in their favour and a valuable feature, proves sometimes a drawback. Thus sannhemp and all the pulse crops which are favourite green manure crops are likewise valuable green fodder crops as well; 'daincha' is very little eaten and wild indigo and *Crotolaria striata* are not eaten at all by cattle. When the crop is to be grown in open unfenced fields with the risk of being grazed down by stray cattle, the most suitable crops will be the latter two. If special pains can be taken, then the first kind of crops can be grown which happen at the same time to be those which germinate readily and make quick and luxuriant growth. One way in which they can be made to serve the double purpose will be to fold cattle or sheep on the fields. The excreta, both solid and liquid, will be left in the soil and these contain practically all the plant food ingredients present in the crop and also much organic matter which is in a better condition for incorporating in the soil. The green crops may be cut and fed in the stalls at home, but as a great deal of waste and loss of valuable plant food takes place in the present methods of gathering the manure this is very inferior to the former as a method of utilisation for the double purpose.

Green Manures Brought from Outside.—There is a large variety of leaves and stems which are brought, cut and carted from elsewhere for use as green manure. In Mysore (and in many other places of India as well) the following are common:—Honge or karanj (*Pongamia glabra*), neem (*Melia azhadirachta*), Tangadi or avare (*Cassia*

auriculata), wild indigo (*Tephrosia purpurea*), Yekka (*Calotropis gigantea*), Ugani (*Lettsomia* spp.).

In the case of the first three a good portion consists of woody branches in addition to the leaves, while in the others the non-leafy parts are more tender and sappy. These are all more or less in a fresh condition and generally not more than a week after cutting and are spread on the puddled soil and trampled in as such, both leaves and stems. They remain buried in the soft mud and decompose slowly. The thicker stems and even the cellulose framework of the leaves remain largely intact and indeed are removed and gathered after the harvest of the rice for fuel in certain parts of the country. Only the green material and the sappy twigs decay and disintegrate and become intimate parts of the soil and serve as a manure proper.

The quantities of these green cuttings applied per acre of rice land varies according to the facility for getting them in any particular neighbourhood, but where facilities do exist and the practice is regular, some three or four tons of the material may be used per acre. In some sections rice is not cultivated without the use of large quantities of honge leaves and in addition to what may be got from the jungle, regular plantations are maintained by land-holders, the trees on which are systematically lopped for manure purposes. Elsewhere a regular supply of the other plants, like wild indigo and tangadi, is derived from the forests and constitute a trade of some considerable magnitude.

Analyses of the materials used give the following figures for the plant foods contained in them :—

Leaves of	N	P_2O_5	K_2O	CaO
Honge ..	1·16	·14	·49	1·54
Tangadi ..	·98	·12	·67	1·06
Yekka ..	·42	·12	·37	·20

HUMAN EXCRETA

Just as the excreta of cattle and other animals form important manures and are used as such, so also the excreta of human beings are to be looked upon likewise and be used for the same purpose. In countries where the population is wholly or in large measure vegetarian in their food and where, as in the case of Japan and China, the density of the population is so great that the keeping of live-stock whether for work on the farm or as food for man, is largely dispensed with, human excreta has to be looked upon as a very important and almost the sole manure available. In such countries the material is collected and stored with great care and is applied to the soil as manure without any portion being wasted. Even in countries which are different in this respect and have plenty of other sources of manure, human excreta as a manure is believed to have such special fertilising value, especially for many vegetable crops that the latter are never cultivated without the use of this manure and the farming

community is not deterred by any feelings of disgust in handling it. Although in India too, small communities especially kitchen gardeners do use the manure to a small extent, such amounts are negligible and in most towns and villages it goes to waste. Village surroundings moreover are made intolerably dirty and foul-smelling, water sources are contaminated and even the soil polluted, forming a menace to health in many ways, a potent cause for the spread of many water-borne diseases like cholera, dysentery, guinea worms, and soil-borne polluting organisms like hook worms. Indeed in certain countries we are told that the harm done is so great that it is customary to abandon villages and shift to a new site every few years. In the towns and larger villages nowadays arrangements exist for removing the material every day from the dwellings by a sanitary staff, but the disposal of the stuff is looked at more from the sanitary angle than from that of its manurial use; the methods aim therefore to get rid of it somehow, even by incineration, if need be.

The chief objection to consider this question from a manurial view-point is the disgusting character of the material and the disinclination of the people to handle the stuff. If methods can be adopted whereby the material loses to a large extent its offensive smell and quality, then the problem of its utilisation becomes easy and practicable.

Composition of Human Excreta

The excreta of human beings contain as a rule more plant foods than the excreta of farm animals, the reason being that the food consumed by human beings is more concentrated than that of farm animals and is also richer in nitrogen and phosphates. This is especially the case among a meat-eating population. In physical condition the material is in a finely ground up condition, the coarse fibrous components of ordinary cattle dung being completely absent. The stuff decomposes very rapidly and should be considered a forcing manure. The composition of human excreta, solid and liquid, is as below:—

	Water	Org. mat.	N	P_2O_5	K_2O	CaO	MgO
Fresh human exrceta (solid)	72·2	19·8	1·0	1·1	·25	·62	·36
Urine ..	96·3	2·4	·6	·17	·20	·02	·02
Mixture of the two ..	93·5	5·5	·7	·26	·21	·09	·06
do. as used in Japan ..	95·0	3·4	·57	·13	·27	·02	·05

The manure is comparatively rich in nitrogen and when used by itself is forcing and leads to much vegetative growth. It has to be supplemented with both phosphatic and potash manure, like bone-meal and wood ashes.

Conservation of the Urine

To some extent as already stated human excreta are collected in the smaller municipal towns and the larger villages by the sanitary staff and are removed by farmers for use as manure. Practically the

whole of the urine is lost in the process and even otherwise the manure is very much mixed with street sweepings and other rubbish and to that extent is poorer as a manure. In Japan we are told that very great care is taken to collect the urine as well, most houses are provided with urinals abutting on the street, as a standing invitation to passers-by to use it, who apparently confer a favour thereby on the owner of the house.

The urine is the more valuable part of the excreta and in view of its high nitrogen content, it has been attempted in the past to collect it all separately and utilise it for the manufacture of urea or ammonium sulphate. It is stated that the amounts available in cities may not be found sufficient to keep any industrial concern going and that therefore it has not been found practicable. It is however worth consideration for small-scale concerns, especially for dealing with the urine from large establishments like jails, hostels, hotels and large offices, schools and colleges.

A new design, both simple and cheap for urinals, has recently been suggested and patented in Sind by M. A. Idnani which appears to hold out promise, although one of the chief difficulties, *viz.*, the large quantity of water which is required for flushing or washing the urinal after it is used and which greatly restricts the capacity of any absorbent which may be used (it is just ordinary earth in the above model) is not got over.

How the Manure is Used

Usually as in the case of cattle manure, this manure also is stored generally in loose heaps in the open, and kept for some time before it is applied to the soil. It undergoes fermentation during the period and there is considerable driage and waste as ordinarily stored. In certain countries notably Japan, the manure is allowed to ferment in special vats with a large admixture of water; a kind of green scum forms on the surface and even ammonia is evolved. In this condition the slurry is carried to the fields and ladled out near the roots of the crops to be manured. More and more fresh excreta are added to the vat, the remains of the previous lot acting like a starter, so that the process is continuous and material for manuring is always available.

The manure is applied to the young standing crop at intervals as and when required as judged by the appearance or the stage of growth of the plants. Great judgment based upon practical experience is exercised in the matter. Market gardeners who use it largely for both Indian and English vegetables apply it at flowering time and again after part of the first flush of crop is picked. Round Bangalore and Mysore, the brinjal crop is the most common one to be so manured. In Japan however the manure is applied to the grain crops as well as to vegetable crops, the cultivation of both of which is of the small-scale garden cultivation type.

Under modern systems of sanitation, *viz.*, the water closet system, human excreta are applied to the soil either after treatment in septic tanks or in towns where no septic tanks are provided, in the raw state, on to sewage grown crops. On these sewage farms heavy crops of cabbage, mangolds and other roots, kohlrabi, cauliflowers, etc., are raised under sewage irrigation and the sewage containing the raw excreta is run onto the fields on which the material is deposited. The author can say from personal experience on one of these farms (Corporation Sewage Farm, Reading, England) that contrary to expectation no offensive smell, such as assails one's nostrils on many ordinary sewage farms, was noticeable.

Forms of Night Soil Disposal

(*a*) *Sewage.*—The most notable sanitary development of modern times is the water closet system of disposal of human excreta. This has become almost universal in the cities and larger towns and it is only a question of time when practically every town of any importance will be served by the system. The sewage carrying the material is mostly let into an adjoining river, sometimes raw but more often (or invariably in modern cities) as a clear effluent after a process of treatment by one or other of several methods of sewage treatment for purification, such as septic tanks, filter-beds, activated sludge tanks and so on. When the effluent is thus let into rivers or streams, the method ceases to be one of utilising it for manure. The main consideration is to make it harmless, by destroying the organic and putrescible matters by thorough oxidation. Very often, however, a sewage farm receives the effluent, where fodder crops of various kinds or vegetable crops are raised and use is therefore made of the material as manure. In whatever way the effluent may be disposed of, great quantities of sludge and sediment which are separated out from the raw sewage, become available as manure for which purpose they are pressed and dried and sold. As already stated the method of disposal of night soil is pursued more from the sanitary angle than from the manurial.

(*b*) *Earth Closets.*—In order to make it available for use as manure for individual farmers night soil is (1) made into a mixture with earth and ashes in the home closets or privies and the stuff made less disagreeable to handle; (2) on a large scale is made into composts, which is an undertaking suitable for municipal towns. Other forms have from time to time been recommended and also put into practice, the most notable one being the making of powderette, which is essentially the dry product prepared by mixing various absorbents like ashes, peat moss, gypsum, etc., and then drying the mixture in the sun or artificially, so that it becomes devoid of the smell and fit for commercial handling, transport, etc.

The earth and ashes compost method is simple and suited for village homes and as a combined sanitary and agricultural practice is worth adoption. The pits may be shallow long ones of any length,

like trenches, some two or more in number which can be used one after the other; if earth and ashes are used regularly after every visit, this method of disposal and utilisation as manure will be free very largely from objectionable features. Even as a method of night soil disposal on a large scale, this wood ashes mixture method is a suitable one, as the resultant mixture has a high manurial value and is fit for transport and distribution.

(*c*) *Composts.*—The compost system recommended for town wastes including night soil is carried out somewhat as follows: The composting is conducted in long trenches in the ground about 30′ long, 8′ broad and 3½′ deep. Usually several of these are dug alongside each other about 6′ apart in a series. Town waste is spread at the bottom of the trench about 6″ thick and then night soil over it in a layer 1½″ to 2″ thick uniformly. Alternate layers are built up in this way till the material reaches about 1′ above the surface; the top layer consists of 9″ of town wastes covered over with 1″ of soil. After about a fortnight the top of the pile sinks about a foot and this is then filled in with further layers of night soil and wastes and covered over with earth. The material is then left undisturbed for about 5 months, after which it is ready for use. (Method adopted in the Mysore State compost scheme.) The resulting product is a black or ashy grey powdery material quite devoid of smell and containing approximately 1% nitrogen. In addition to reducing the night soil into this unobjectionable form it also converts the coarse bulky town sweepings into a similar powdery condition and at the same time kills the seeds of many noxious weeds which become very troublesome in the fields when the sweepings are applied as such, without composting.

CHAPTER XI

OTHER CONCENTRATED MANURES

ORGANIC NITROGENOUS MANURES

WE may now deal with the manures which supply largely any one or other particular plant food such as the nitrogenous, phosphatic and potash manures. These are all concentrated manures compared with those considered so far; they are not farm-produced but are either manufactured products or natural products obtained from outside sources and have to be purchased as commercial products. The nitrogenous manures are by far the most important and may be classified into two heads, according as they are organic or inorganic.

Kinds Available and Characteristics

Organic Nitrogenous Manures.—These comprise (1) oilcakes; (2) Peruvian guano; (3) various animal products like fish meal, and scrap, dried blood, slaughter-house refuse or tankage, wool waste, tannery refuse, horn, hoof and leather meal and bonemeal.

Oilcakes

India produces a great variety of oilseeds, *viz.,* castor, groundnut, gingelly, niger, safflower, rape, linseed, cottonseed, cocoanut, neem, mahua (*Bassia latifolia*), punnai (*Calophyllum inophyllum*) and honge (*Pongamia glabra*). The seeds contain in addition to the principal ingredient, *viz.,* oil, a high percentage of proteids. When the oil is extracted from the seeds, the residue or oilcake becomes much richer in proteids, which may go up over 50% corresponding to a nitrogen content of about 9%. The oilcakes are therefore valuable nitrogenous manures. Many of them however are edible and form important cattle feeds and cannot therefore be thought of for use as manure, except where, as in the case of groundnut cake, there is a very large production. The edible cakes too can be turned over for manure if they should become rancid, stale and otherwise unfit for cattle feed. The latter class of edible cakes and the non-edible class all become available for use as manure. The oilcake from 'mahua' seeds is in exception among the non-edible cakes and it cannot be used as manure as it acts injuriously on crops on account of the saponin contained in it.

The oilcakes are quick-acting manures; their effect can be seen strikingly within a week after the application, generally in the deeper green colour of the leaves. The rate of such action will depend of course upon the ease with which they nitrify in the soil, and in this respect they differ to some extent from each other. Castor oilcake is found to nitrify quicker and become available sooner than the others. Cakes applied so as to supply the same quantity of nitrogen show differences in their effect on crops. According to European

experiments conducted on maize, the effect at the same nitrogen level with the different cakes was as below: Taking sodium nitrate as 100, castor cake was 85, linseed meal 80, cottonseed meal 76, castor cake at its worst 74. Though exactly similar data are not available in Indian conditions, it is true that castor cake does act better than other cakes at the same nitrogen level.

How Applied.—Oilcakes should be well powedered before application, so that the manure may spread uniformly in the soil. Cakes are often sold as a meal or powder; but there is always the risk of adulteration to be feared and guarded against. One method of application is to soak the cake in water and mix the mash with the irrigation water. Oilcakes are as a rule used only after the crops have made a certain amount of growth and not at sowing time; in the latter case if the cake has not been thinly and uniformly spread then lumps may rot here and there and damage the sprouting seeds. If applied later on, the well-developed root system will readily utilise the manure. As a matter of fact roots usually crowd around little bits of oilcake in the soil at this stage, with evident advantage.

Although nitrogen is the most important constituent of oilcakes, they also contain small percentages of phosphoric acid and potash, while their total organic matter content is also a very valuable feature. This is much in their favour as against the inorganic nitrogenous manures described later.

As against the bulky organic manures like farm-yard manures, green manures, etc., their effect is confined to the crop to which they are applied. In about 6 weeks, nearly all the nitrogen is nitrified and is therefore used up by the crop. There will be no residual effect, worth mentioning. For the same reason, the total dose decided upon should be applied in two or more instalments rather than in one dose, so that the nitrates formed may be only in such quantities as the crop could utilise at any particular stage.

Nitrification of Oilcake Nitrogen.—In this connection the following results showing the rates of nitrification of some of the oilcakes will be found useful. In laboratory experiments using the red loamy soils of the Hebbal Farm, Bangalore, the different oilcakes nitrified at the rates shown below:—

	Percentage of oilcake nitrogen which had nitrified after			
	2 weeks	4 weeks	6 weeks	8 weeks
Groundnut oilcake ..	26	46	57	57
Black castor oilcake ..	23	43	57	57
Ippe or Mahua ..	0	0	0	0
Honge ..	25	36	45	52
Neem ..	22	36	45	57
White castor ..	23	40	60	80

(Adinarayana Rao, in *Jour. Agr. & Exp. Union*, Mysore, July 1920).

It will be seen that in 8 weeks fully 80% of nitrogen in the white castor cake was nitrified, as against only 57% in the best

among the others. Mahua cake on this type of soil does not nitrify at all during this period and is apparently useless.

Farmers sometimes show a preference to oilcakes made in the country *'ganas'* (oil mills of wood or stone) over oilcakes from the more efficient mills or expellers. The former type of cakes contain more oil than the latter, and this to some extent prevents them from nitrifying as quickly as the others and are hence somewhat slow-acting. They are believed to have a more lasting effect. Where basal doses of farm-yard or green manures have been applied, as they nearly always are in practice there is nothing to be gained by resorting to the slower-acting kinds among oilcakes in preference to the richer and more quick-acting kinds. As a general rule, which is applicable to all quick-acting manures and especially the artificial fertilisers like sulphate of ammonia, nitrates, etc., it will be better to divide up the total nitrogenous dose between slow-acting and quick-acting manures and to adjust the application of the latter to particular stages when stimulation of growth may be necessary and can be secured most effectively (see also under 'Sulphate of Ammonia').

Need for Abundant Soil Moisture.—It must be also noted that the application of oilcakes (as indeed of all concentrated manures) should be followed by plentiful irrigation (in the case of irrigated crops) or that the application should be made when the soil contains enough moisture and in the season when moderate showers prevail. In the absence of sufficient water especially in the case of irrigated crops for which heavy doses are applied, the full benefit may not be secured, because both the absorption and the larger transpiration for better growth will need a large supply of water. Furthermore, there may be even the risk of scorching on account of the high concentration of plant food salts in the soil solution, which may generally occur in patches owing to uneven distribution of the manure. With the ordinary doses usual in practice and the irrigation usually given, the latter seldom occurs, but it is well to bear in mind the need and the role of water in this connection.

The crushing of the seeds is conducted in small country mills of stone or wood, driven by one to two pairs of bullocks, in iron rotary mills driven by engine power, in hydraulic presses and in the so-called oil expellers. Varying amounts of oil are left in the cake in the different processes and the more efficient the process, the less the oil left in the cake. In the above list the processes are in the ascending order of efficiency. Oil is sometimes extracted by chemical solvents, in which case the seed is thoroughly exhausted and the cakes contain no oil. The nitrogen content of the cakes is in inverse ratio to the oil content (in each case) and the more the oil, the less is the nitrogen and the poorer is the cake as manure. Even in the same kind, oilcakes are variable in quality according to the method of crushing employed, to the amount of hulls or husks included, to the variety of the seed used and to the purity or amount of adulteration.

The seeds may be hulled (deprived of the husk or decorticated) before being crushed, or the hulls may be present, not being removed at all, or removed only partially or even purposely put in. The higher the proportion of hulls, the less of course is the nitrogen content. Admixture of hulls is especially the case with safflower cake, castor cake and cotton-seed cake. The last is put out in two well-recognised forms, *viz.*, decorticated cake and undecorticated. In some cases variation in nitrogen may be due to variety; in the case of castor there is a white castor and a black or brown castor, in which the shelled seed or meat is white or brown in colour. The former has the higher nitrogen content.

Wilful adulteration is of course always possible and is sometimes resorted to. The adulterant is usually mere earth or sand and some of the hulls. The mixture may take place during the crushing itself, or, in the case of cakes sold as ground meals, in the meal or powder. It is therefore a safe course to purchase oilcakes, when they are required in large quantities on the basis of a guaranteed nitrogen content, as the result of chemical analysis.

Nitrogen Content of Oilcakes

The following table gives the nitrogen content of the ordinary oilcakes and incidentally the variation which has been noticed in the percentage :—

		Percentage from
White castor cake	..	4·2 to 8·69
Black castor cake	..	3·99 to 4·89
Hongey cake	..	3·37 to 4·11
Neeem cake	..	3·89 to 5·99
Safflower cake	..	2·58 to 8·30
Groundnut cake	..	7·89 to 9
Gingelli	..	4·93
Ippe (Mahua)	..	1·80 to 4 84
Cocoanut cake	..	3
Punnai cake	..	4

Fish Manure (Fish Meal, Dried Fish, Fish Scrap)

Among the organic nitrogenous manures of animal origin available in India, dried fish and fish products are of some importance, especially during certain years or succession of years, when immense shoals of sardine fish are caught near the coast. Fish oil is extracted from these in small boiling plants and the residue is available as manure. In ordinary years also surplus dry fish and fish scrap are available along the coast to some extent. All these fish products are both nitrogenous and phosphatic manures and will contain 4% to 5% of nitrogen and about the same percentage of phosphoric acid. They often contain considerable salt (sodium chloride) in addition. Due to the crude drying on the seaside there is also much admixture of sand which is also sometimes added by wilful adulteration. The material is very evil smelling and this is a feature rather objectionable in handling; it also attracts stray dogs and jackals, which

play havoc in the soil round the roots of the manured trees or crops. The salt is considered favourable for cocoanut trees, to which indeed along the coast fish manure is largely applied.

Bonemeal

This is predominantly a phosphatic manure and is described more fully under that head. It contains about 3% to 3·5% nitrogen, when it is made from raw bones. Bones are sometimes treated with steam to recover the gelatin, and the residual bone then contains little or no nitrogen. If the bonemeal is finely ground then on good moist soils, it nitrifies readily, almost as well as the nitrogen in oilcakes.

Other animal wastes or slaughter-house products such as dried blood, tankage, etc., assume importance in countries where large public abattoirs or huge meat packing houses exist as in Chicago and many other American cities. All kinds of offal and the non-meat portion of the carcasses are converted into manure by drying and powdering them raw or more generally after steaming for recovering fat and gelatin. Likewise enormous quantities of blood are also dried either raw or as is more often the case, after the recovery of albumin, and is sold as 'dried blood' for manure. They are of little importance in India yet, except in a small way and in large cities.

Dried Blood

This is perhaps the most important among these products and it is a highly nitrogenous manure. It is a black, dry, clotted or gritty sort of powder and contains up to 10% nitrogen. It may be said to be the most quick-acting among the organic nitrogenous manures of this class. It ferments very quickly and is best used largely diluted with inert material like ordinary earth or soil, so that it may be distributed thinly in the soil. It is best used of course for the standing crop on account of its quick-acting quality.

Tannery Refuse

This consists of the scrapings of flesh, bits of leather, hair, etc., with considerable admixture of lime from the liming tanks. It has to be used with great caution, as scrap and such refuse from tanneries which use chemicals like chromates and arsenites may prove injurious to crops on account of the admixture with such salts. In any case these are slow-acting manures and especially so when leather scrap predominates in quantity. The lime however does good in some soils and the material from tanneries using only the tan bark process may be brought and applied with advantage.

Wool Waste

Large quantities of wool waste are obtainable in the nighbourhood of wool spinning and weaving factories, which are brought up

for manure. The material comprises not only waste wool but also a lot of earth and dirt separated out from the bulk, which reduces its value considerably. The wool waste itself may contain 4% to 7% nitrogen. It is a slow-acting bulky manure and is generally kept stored in the fields for months before it is used. It is nevertheless rather a popular manure for potatoes and large quantities are bought (in Bangalore from the local Mills) by potato growers. In imperfectly washed wool there may be a fair percentage of potash, which perhaps accounts for this preference. It is also noteworthy that within one crop season the manure completely decomposes and not a trace can be seen in the fields after the crop is gathered.

Silkworm Waste

In the silkworm rearing tracts (of Mysore, Bengal and Kashmir) large quantities of waste composed of the uneaten remains of mulberry leaves, the excreta of the silkworms and the pupæ and waste from the reeling houses become available as manure. It is considered a fairly quick-acting manure, the excreta especially, and may contain on the average up to 10% nitrogen.

Guano

A nitrogenous manure of animal origin which comes in a separate class is Peruvian Guano. This material is made up of the excreta and the dead remains of myriads of sea birds, which congregate on certain breeding grounds. Vast quantities have accumulated sufficient to be almost mined and transported, and in the early days of the discovery very large quantities were available and the guano was indeed a manure of first class importance. Accumulated under rainless conditions or in protected situations, guano is exceedingly rich in nitrogen, and its effect was practically equal to sulphate of ammonia. Deposits from situations exposed to rains contain very much less nitrogen and sometimes none at all and were practically only phosphatic manures in character and were called accordingly 'phosphatic guands'. The former which contain both nitrogen and phosphoric acid has the following composition, *viz.,* nitrogen up to 19% and P_2O_5 some 5%, while phosphatic guanos contain up to about 36% P_2O_5 and hardly ·5% or 1% nitrogen.

Unit Values

For comparing the relative values of oilcakes (and of other manures also) the cost is calculated for a 'unit' of nitrogen (or of other ingredient). The cost per unit is arrived at by dividing the cost per ton by the percentage of the nitrogen. Thus, if an oilcake with 5% nitrogen costs Rs. 70 per ton, the cost per unit of nitrogen is Rs. 14; similarly if an oilcake with 4% nitrogen costs Rs. 60 a ton, then a unit of nitrogen in it costs Rs. 15, so that the latter is dearer at Rs. 60 than the former at Rs. 70 per ton.

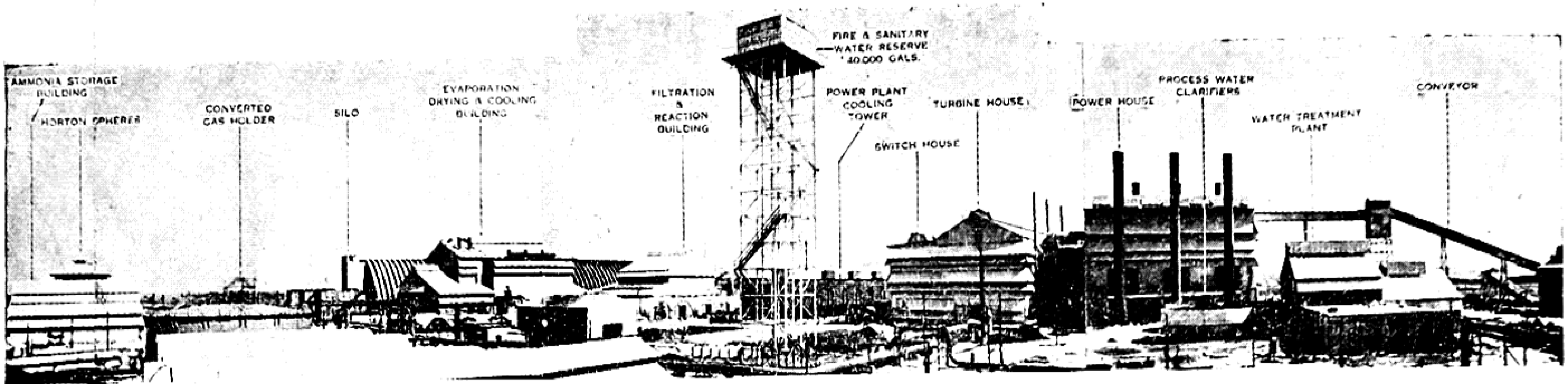
If a manure contains both nitrogen and phosphoric acid, then the latter will have to be allowed for, and for this purpose the nitrogen is taken as four times the value of the P_2O_5 (lb. for lb.) and eight times that of potash. If a sample of fish manure contains 4% nitrogen and 4% P_2O_5 and costs Rs. 60 a ton, then the unit of nitrogen in it costs Rs. 12 and a unit of P_2O_5 Rs. 3; where potash is also present, a similar calculation is made to allow for it also.

The Chemical or Artificial Nitrogenous Fertilisers

Nitrate of Soda (*Chili Saltpetre*).—It has already been explained that the nitrogen can be taken up by plants only in the form of nitrates (with the exception of puddle grown rice) and that all nitrogen-containing manures have to nitrify in the soil before they can be of use to plants. It is obvious therefore that nitrate manures will be the most readily available and quickest-acting manures. The nitrates available as manures are the nitrates of soda, potash and lime, and recently ammonium.

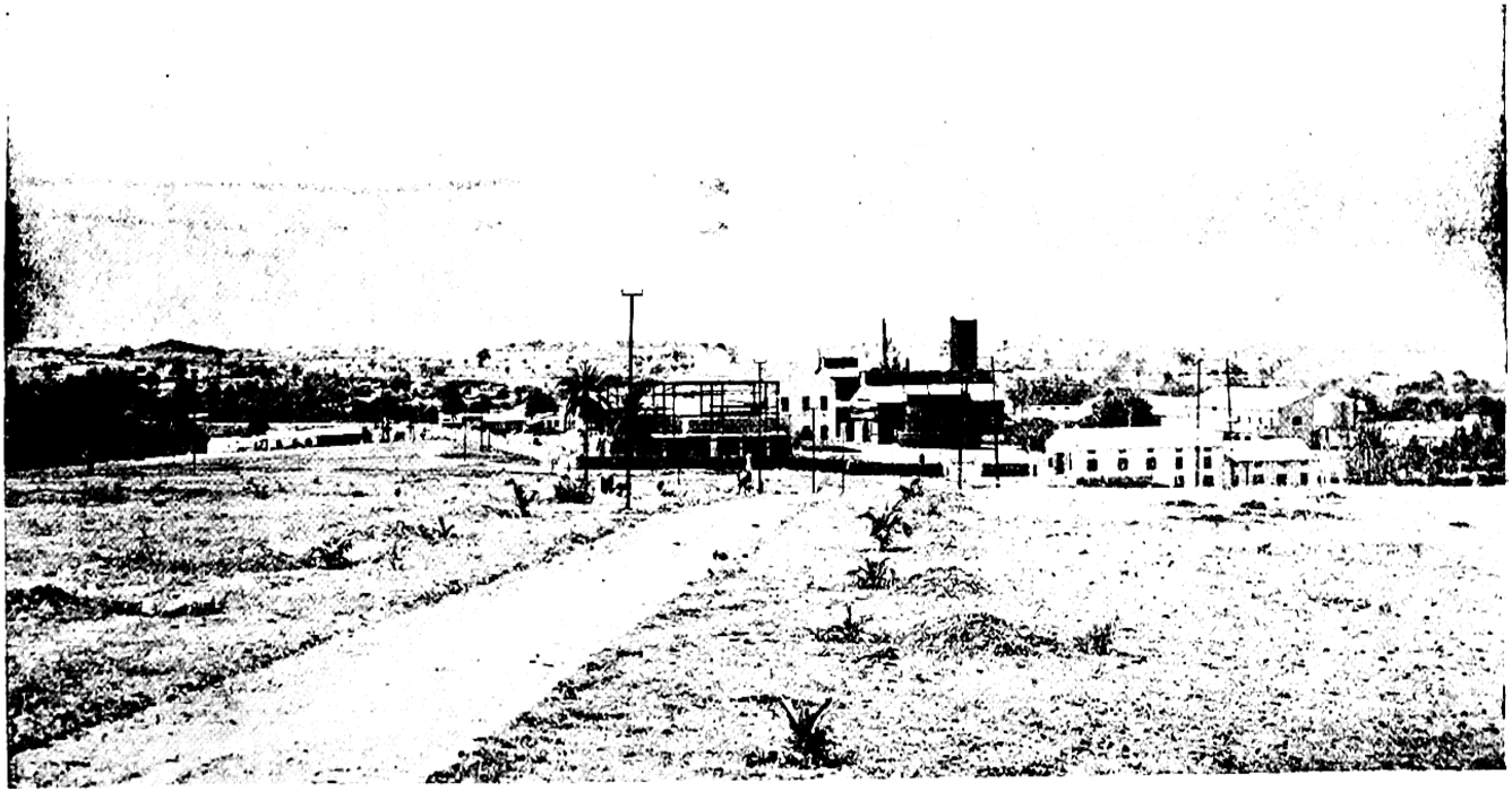
Sodium mitrate, also called Chili Saltpetre, is obtained mainly from Peru and Chili where vast areas are covered with a thick incrustation of the crude salt; this is collected and purified into the commercial product. It is used largely both as a fertiliser and as the raw material for the preparation of nitric acid. It contains about 16% nitrogen. It is readily soluble in water, it also absorbs moisture from the air and becomes moist and this property makes storage difficult. It is the quickest acting among nitrogenous manures and is indeed taken as the standard for comparison, others being expressed as percentages of the nitrate. Like all quick-acting manures it has to be applied to the growing crop and preferably in more doses than one and the field is to be irrigated soon after, to ensure proper diffusion and distribution and to prevent undue concentration at any point where it may cause scorching. Sodium nitrate has the drawback that it deflocculates the soil and has therefore to be used with caution, especially on clayey soils; repeated applications will seriously injure the physical condition of these soils, unless the soils are also adequately limed. It should be stated however that sodium nitrate does not deplete the soil of lime, but has on the other hand a protecting effect on it. Sodium nitrate has been found deleterious to the crop if applied to puddle grown rice, as it denitrifies under this condition and nitrites are formed which are poisonous to plants. On all other crops, used with caution and in moderate quantities, it is an excellent manure and produces striking and rapid effect. There is however the tendency to over-luxuriant growth to be guarded against which is a risk common to all nitrogenous fertilisers.

Potassium Nitrate (*Saltpetre*).—This nitrate is more or less of the same order as regards its quick-acting effect as Chili Saltpetre. Its additional content of potash makes it a *double* fertiliser supplying both nitrogen and potash. Crude saltpetre contains 3·63% of



The mammoth Fertiliser Factory of the Government of India, at Sindri, with a production capacity of 3,50,000 tons of Ammonium (Synthetic) Sulphate per year—Panoramic view.

Photo by Courtesy of Manager



Ammonium (Synthetic) Sulphate and other Fertiliser Works of The Mysore Fertilisers and Chemicals, Ltd., Belagola, Mysore State.

Block by Courtesy of the Company

nitrogen and 16·71% potash and refined saltpetre about 13% nitrogen and 40% potash. As the material is much costlier and is also required for the making of gunpowder it can be obtained for manurial use only in limited quantities. It is free from the defects of sodium nitrate as regards the capacity to absorb moisture from the air and the consequent difficulty of storage, and also as regards its harmful effect on the physical conditions of the soil. It keeps dry and does not destroy flocculation in the soil. It is a highly stimulating manure, on account of its being a nitrate and at the same time a supplier of potash. The other precautions regarding small doses, frequent irrigation, etc., mentioned under sodium nitrate apply to potassium nitrate also.

The crude nitre is obtained from the so-called "nitre beds". In this method urine and many other nitrogenous wastes are heaped up, allowed to nitrify together with wood ashes and the material is then moistened with plenty of water and the drainings or effluents are collected, evaporated and allowed to crystallise. The process is a good illustration of the ordinary process of nitrification by bacterial agency.

Sulphate of Ammonia.—Sulphate of ammonia may be said to be the most general and important nitrogenous manure available at the present time. Until a few years ago the gas liquor obtained in coal gas plants was the only source of commercial sulphate of ammonia and the quantities available were limited and the production was confined to coal-producing or coal gas-using countries. At the present time, thanks to the process developed for the fixation of atmospheric nitrogen, the material is available in practically unlimited quantities and the production can be undertaken in any part of the globe, provided abundant electric power (usually hydro-electric) is available. The atmospheric nitrogen can be fixed in combination with carbon and lime into calcium cyanamide (the 'Frank and Caro' process), with oxygen into nitrates (the 'Birkeland and Eyde' process) or with hydrogen into ammonia (the 'Haber-Bosch' process). The last one bids fair to become the method *par excellence* and to be taken up exclusively. The ammonia produced in the combination (or fixation) is made to combine with sulphuric acid (which generally forms part of the same manufacturing plant) into ammonium sulphate.

In another process the need for sulphuric acid for this purpose is dispensed with; the ammonia is made to combine with carbon dioxide and become converted into ammonium carbonate, which, thereafter is made to react with calcium sulphate or gypsum and become ammonium sulphate. This process avoids the need for sulphur which will have to be used when sulphuric acid has to be prepared; as sulphur is becoming almost unobtainable nowadays, this method is a great advantage. It is this method called the "gypsum process" which is adopted by the new factory in Sindri in Upper

India, which is said to be the largest ammonium sulphate factory in Asia.

As a manure, sulphate of ammonia is both soluble in water and quick-acting. The ammoniacal nitrogen has to nitrify in the soil and be converted into nitrate before it can be taken up by plants and for this purpose moisture, aeration and the presence of lime are necessary conditions. Rice is the only crop which can utilise the ammoniacal nitrogen and in all other cases nitrification has to take place before it can be utilised by plants. Repeated and heavy doses of ammonium sulphate, without adequate supplies of lime in the soil, either naturally present or added in the shape of manures, will lead to acidity in the soil, and if left uncorrected will lead to permanent injury of both the physical condition and the capacity to maintain the desired vegetation. Lime is required not only for combining with the nitrate as it is formed but also with the sulphuric acid as it is liberated. Lime will be required also to replace whatever may be lost from the soil in the shape of sulphate of lime.

Other remarks already made in regard to quick-acting manures, the nitrates of soda and potash, apply to sulphate of ammonia as well. One important additional caution is however the fact that although the presence of enough lime in the soil is very essential, the sulphate of ammonia itself should not be mixed or brought into contact with slaked or unslaked lime or alkaline carbonates, wood ashes or basic slag, as this will cause the liberation of ammonia and its loss into the air.

Calcium Cyanamide.—This material is also a product of the fixation of atmospheric nitrogen and is available as one of the chemical manures. In contact with moisture in the soil it gives off ammonia which of course will have to undergo nitrification before the nitrogen can be utilised by the crop. During this conversion into ammonia there is risk of loss of part of the ammonia; in addition it has been found to hurt the germination of the seeds if the sowing is done immediately after the manure is applied to the soil. Unlike other quick-acting manures, cyanamide has to be applied not to the growing crop but to the soil and that too some considerable time, at least 10 days, before the seeds are sown. It is in the form of a finely ground black powder, rather lumpy in storage and has to be kept in a dry condition. The nitrogen content of the material will be about 18% to 21%. It has also a 'sterilising' effect on the soil, as it kills various moulds, fungi and nematodes.

Calcium cyanamide has, on the whole, to be applied with considerable caution especially when it is to be applied to the growing crop. The material has to be of the kind specially treated or "oiled" before it is put out for sale; in the untreated condition it is highly irritant to the eyes and nose of those handling it. It undergoes deterioration in storage, and has to be well protected against moisture, and in any case storage for long periods is undesirable and the material is to be applied preferably when new. Under certain

soil conditions, especially where excess lime is present or the manure is not mixed intimately and uniformly in the soil, both inert and deleterious compounds may form in the soil.

Other Nitrogenous Artificial Manures.—There is a large variety of artificial nitrogenous manures, which have come into the market within recent years, some of which contain not only nitrogen, but also phosphoric acid, potash and lime. These are all highly concentrated and are made purposely so, in order to make them compact and less costly in transport. Those containing nitrogen alone are the following:—ammonium nitrate, ammonium chloride, nitro-chalk; the first is of course the most concentrated in nitrogen but it is subject to the risk of becoming a dangerous explosive under certain circumstances (such as in storage near sulphur, cotton or wool waste or similar easily oxidisable and inflammable articles) and also becoming moist when exposed to the air. The second is free from both objections, while the last is a mixture of the first with chalk and contains therefore lime in addition. The nitrogen content is as below :—

Ammonium nitrate	..	..	..	36%
,, chloride	..	..	..	26%
Nitro-chalk	..	..	..	15·5%

Combinations with other plant foods are those in which the ammonia is combined with phosphoric acid; of these many commercial products are available, the differences being due to the proportions in which the two are combined. The process of extracting elemental phosphorus from various phosphates has made the manufacture of these combined fertilisers in the electric furnace simpler. Pure phosphoric acid is obtained by the process and this is made to combine with ammonia, potash, lime or soda as desired, giving highly available forms of phosphatic manures. The following are some of these fertilisers together with their composition :—

Name		N	P_2O_5	K_2O	CaO
Ammophos A	..	10·7	46	..	..
,, B	..	16	20	..	..
Leunophos	..	20	20	..	..
Nitrophoska	..	16	19	16	..
Urea phosphate	..	18	45	..	..

Urea.—A purely nitrogenous fertiliser among the above class is 'urea' which has been put out under the trade name of 'floranid'. This is a very soluble and highly concentrated fertiliser containing about 46% nitrogen. In contrast with ammonium compounds from the solutions of which ammonia is fixed by the soil near the surface where it is applied, the urea has the property of diffusing as such deeper through the soil going down as the solution percolates, where, as it nitrifies, it is absorbed by the roots of the crop. As in the case of all quick-acting fertilisers irrigation is necessary after manuring, in order to prevent concentration. It may be added that in order

to be safe, concentrations in soil water should not exceed ·5 parts of salts per 1,000, and should be preferably much lower at about one half the above strength.

An observation of peculiar interest is that urea in sufficiently dilute solution can be applied as a spray over the crop. It is reported that wheat plants can absorb it through the leaves and utilise it as a nitrogenous fertiliser. Applied when the wheat plants are near the flowering stage, it results in an increase in the protein content of the grain and in a higher yield of the grain itself. (E. K. Macintyre, in Farm Paper Letter, of the U.S.A. Department of Agriculture.)

Anhydrous Ammonia or Liquid Ammonia.—Liquid anhydrous ammonia instead of ammonium sulphate has recently come into use as a method of nitrogenous manuring in the U.S.A., the Hawaiin Islands and elsewhere. Suitable machinery or 'applicators' has been designed for the purpose in which the supply of liquid ammonia is carried in pressure containers from which the liquid flows through narrow flexible pipes which open into furrows behind cultivator teeth or tynes working into the soil to a depth of 5" or 6". The liquid (which as a matter of fact gasifies as soon as it enters the soil) is reported to be readily and entirely absorbed by the soil, although this appears doubtful and there is the risk of some of the gas escaping unabsorbed. The liquid ammonia contains four times as much nitrogen as the same weight of ammonium sulphate and there is consequently much saving in transport. In respect of manufacture it dispenses with the need for sulphuric acid, which is a matter of great importance in the larger interests of the country. The nitrification and the absorption should be quicker than in ammonium sulphate (or in compounds other than nitrates). Liquid ammonia is moreover already being made and supplied in India by the present ammonium sulphate factories, to the numerous cold storage establishments and dairies. Liquid ammonia containers suitable for mounting on the 'applicators' can therefore be easily had and a suitable applicator itself can be easily designed and manufactured. In the Mysore Department of Agriculture, such a machine has already been designed and fabricated and the new method tried experimentally.

It must however be noted that neither the handling nor the application is so convenient or fool-proof as with ammonium sulphate which can be easily spread or broadcast, as a dry powder. The risk in the handling of pressure containers is not small and it is doubtful if it will be wise to put them into hands of the ordinary cultivator. Moreover at present prices the cost per lb. of nitrogen in liquid ammonia (even at concession rates) is almost the same as in ammonium sulphate, and there is therefore no special advantage to counterbalance the difficulty of application. If it is a question of dispensing with the need for sulphuric acid in the manufacture, a more suitable product will be urea, which is a highly concentrated product and presents no difficulty in application.

PHOSPHATIC MANURES

Phosphatic manures comprise the following :—

(1) Bones, either raw or steamed; (2) Bone charcoal; (3) Mineral phosphates, phosphatic rocks, phosphatic guanos; (4) Superphosphates, which are only one or other of the above treated with strong sulphuric acid; (5) Basic Slag or Thomas Phosphate; and (6) the new combined nitrogenous and phosphatic fertilisers of the ammophos type.

Insolubility of Phosphates.—One of the chief properties which differentiates the phosphatic from the nitrogenous and the potash fertilisers is their insolubility in water and the impossibility of maintaining them in the soluble condition even after they are converted at great cost into the soluble form. In the primary sources, *viz.*, bones and rock phosphates, the phosphoric acid exists as calcium phosphate or the phosphates of iron and alumina in addition, all of which are quite insoluble in water. Soluble phosphates moreover go into combination with the iron and aluminium when applied to the soil and become insoluble again. While this is a bad feature from one point of view, it is a good feature nevertheless, because all phosphoric acid becomes fixed in the soil and therefore no loss by solution and leaching out can take place and all phosphates are thus conserved in the soil, unlike the nitrates and other soluble forms of nitrogen or the salts of potash.

Plants are however able to take up the phosphate they require from the insoluble form in the soil or applied as manure, because the root sap is slightly acid in character and is able to dissolve out minute quantities. Very small traces can be dissolved out by water containing carbon dioxide dissolved in it, and even by plain water itself, but these quantities are negligible. The amount of such available phosphoric acid can be determined by treating the soil with a dilute solution of citric acid by the Dyer's method referred to already, which is a method in which the action of the slightly acid root sap is imitated. It is an extraordinary circumstance that it is from such traces absorbed from the soil that animals of all kinds (which are sustained by the vegetable kingdom) obtain the large quantities of calcium phosphate of which their bony skeletons are chiefly made up

The chief problem then in connection with phosphate manuring is that of supplying it in a soluble form. The manufacture of superphosphate of lime by treating insoluble phosphates with strong sulphuric acid has afforded a partial though important solution of the problem and is indeed a classical and memorable landmark in agricultural development. The method has held the field exclusively until very recently, when the soluble compounds of the ammophos type began to be manufactured. Even with these the ease with which transformation into insoluble forms takes place in the soil is a difficulty.

Placement of Phosphates.—Another difficulty with phosphatic manures may also be mentioned in this connection, which is that if the manure is applied on the surface the top layer of the soil fixes it, although the plant food is required in the deeper layers which the plant roots traverse. The question of placement therefore also becomes important, unlike in the case of the nitrogenous and potash manures which can be and are mostly given as a top dressing, because the soil water can wash the nitrified nitrogen down into the root zone with great ease. Phosphatic manures have on the other hand to be worked in at least 3" and up to 4½" below ground.

It has been found that in the presence of abundant organic matter in the soil, the availability of the phosphoric acid is increased and that, in addition, the tendency to fixation into insoluble forms is much reduced. It is therefore essential that good doses of organic manures like farm-yard manure, green manure, etc., should be given along with phosphatic manuring.

The various phosphatic manures may now be dealt with individually:—

Bones.—For application as manure, bones will have to be crushed and reduced into a powder, coarse or fine; this makes it easy to spread evenly and what is more important, it is then in a condition when it can be attacked by plant root sap more easily and therefore can be more available. Bones are crushed either raw or after being steamed to remove the fat and gelatin; when thus fat-free, crushing is less difficult and the availability is also more. Bones are very hard and powdering is no easy matter. Powerful disintegraters are required and the work is done in special bone-crushing mills; but this is quite essential for its use as manure.

Composting Bone.—Attempts have been made to soften bones for application as manure on a small scale and these have taken the form of some kind of composting, in which bones broken into lumps are heaped in alternate layers with ashes, earth and cattle manure and then watered with urine every day. Another method makes use of bacterial action on sulphur, which is mixed with the heap and which is oxidised by bacterial action; the acid acts upon the phosphate and brings it into solution or at least disintegrates or corrodes the material. Bones are however exceedingly resistant and have been found to remain almost intact in the soil for many years.

In the shape of bonemeal, however, composting with sulphur is reported to render the phosphoric acid considerably more available than it is in raw bones or bonemeal. The method of composting recommended for the purpose is to first activate the sulphur by mixing 5 parts of soil, 1 part of water and ½ part of sulphur and keeping the mixture in a pot for a fortnight. The inoculum so prepared is added to a mixture of 100 parts of bonemeal, 25 parts of finely powdered sulphur, 75 parts of sand, 16 parts of charcoal dust and 60 parts of water. The mixture is occasionally watered and turned over and the compost becomes ready in 3 months.

To what extent bonemeal proves beneficial in Indian soils for the different crops is difficult to say. In many parts of the country it has been found decidedly beneficial in the case of the rice crop. In Japan indeed it has been found almost as good as superphosphate (in experiments reported by Kellner). Kellner also found that the effect of the bonemeal phosphate was felt over the following three years after the application, thus making it out as a lasting manure. For the same reason bonemeal will be found a very desirable manure for orchards and plantations of permanent crops, along with nitrogenous and potash manures. Bonemeal manure is suitable for most soils, including those with a high iron alumina content. Application of bonemeal in conjunction with green manures is a means of making it more useful. On the lighter loamy soils bonemeal will be found to act better than on the stiffer soils, on which the aeration is not so great.

Raw bonemeal will have a nitrogen content of 3% to 4% and a phosphoric acid content of 20% to 22%, while steamed bonemeal may have little or no nitrogen and about 24% of P_2O_5.

Bone Charcoal or Bone Char, or Bone Black.—Is the charred material prepared by subjecting bones to a kind of dry distillation and powdering the "charcoal" so obtained. It is used for decolourising sugar or jaggery solutions in sugar refineries. It is used over and over again for this purpose after a process of revivification but when it is thoroughly 'spent' it is discarded and then is available for use as manure. The charring effectively prevents decay and the charcoal is even more slow-acting than ordinary bones and is useless in that condition as manure.

Bone ash is practically pure calcium phosphate and is obtained by incinerating bones; the finely divided condition in which the phosphate exists renders it a little more useful but it also belongs to the same class of very slow-acting manures.

All these three, *viz.*, bones, bone charcoal and bone ash form only the raw material for making superphosphates and are utilised in that manner, raw bones being however a poor material for the purpose.

Rock or Mineral Phosphates.—Large deposits of phosphate containing minerals occur in many parts of the world, which at present form the world's principal sources for phosphate manure. The phosphatic component of these mineral rocks is tricalcium phosphate and this occurs in conjunction with calcium carbonate or limestone along with ordinary clays containing much iron and alumina. An important associated mineral is calcium fluoride, which is a characteristic feature of the mineral apatite. Mineral or rock phosphates occur as rocky beds, nodular concretions or pebbles, in many countries such as the U.S.A., Canada, North Africa, Russia, Egypt, the Nauru and many Pacific Islands. In India phosphatic nodules occur in the district of Trichinopoly. The tricalcium phosphate is present in varying quantities in these rocks; good deposits may contain up to

90% ; anything below 40% is not considered good enough for being worked. Iron and alumina are serious but common impurities and greatly reduce the value of the rock anything over 5% being considered too high.

Rock phosphates may be used as manure as such but the general practice is to convert them into superphosphates. When they are to be used as such then they have to be ground very fine into an impalpable powder (or "floats"), the finer they are the better they are made use of by plants. Thus, taking superphosphate as 100, the response to finely ground rock phosphate by various plants ranges from 33 in the case of wheat to 83 in the case of white clover (*Commercial Fertilisers*, by G. H. Collins).

The availability can be improved by (1) composting with green manures, (2) composting with earth, manure and sulphur as already stated for bonemeal. The former of course is simpler and worthy of adoption. In fact rock phosphate 'floats' can prove quite beneficial on soils with a high organic matter content, and are always to be applied along with a heavy dose of cattle or green manure.

The conversion of rock phosphates into superphosphate by means of sulphuric acid is the most important method of utilisation but to a small extent another method is also employed, in which the material is fused with crude soda earth (Magadi Soda) and converted into sodium silicophosphate which is a product easily soluble in dilute citric acid.

Basic Slag or Thomas Phosphate.—In the making of steel from pig-iron, the latter has to be freed from all impurities, including phosphorus and this is effected by lining the furnace with lime. In the intense heat of the furnace the latter combines with the oxidised impurities and rises to the top as a slag, which is allowed to flow out. On cooling, the slag is broken up and ground fine and containing as it does all the phosphorus as calcium phosphate it is utilised as manure, under the name of 'basic slag'. Much free lime is also present which may amount to 40%, and the material is strongly alkaline. The presence of the lime is a great advantage for many soils. The grinding into very fine powder is very important and in this very finely divided condition it is considered next only to superphosphate in action. Occasionally calcium fluoride may be present as an impurity and this is toxic to vegetation. It must be made sure therefore that this compound is not present in the material to be used. The content of P_2O_5 in 'basic slag' is variable and may range from 8% to 15%.

Superphosphate.—By far the most important and commonest form in which phosphate manuring is given is that of superphosphate of lime. Nearly all the phosphatic materials described so far form the raw material for the manufacture of superphosphate. The method of manufacture consists in treating the ground or pounded raw material with strong commercial sulphuric acid, using such quantities

of the material that in the reaction no surplus or free sulphuric acid will be left. Rock phosphates are sometimes purified by the separation by washing out of all non-phosphatic material and the purified rock is used. During the treatment with sulphuric acid, the insoluble tricalcium phosphate is converted into soluble forms, part of the lime combines with the sulphuric acid and forms calcium sulphate, and the other bases like iron and alumina are also converted into sulphates. The resulting product called superphosphate of lime is a mixture therefore of all these compounds. The important reaction is of course the conversion of the insoluble tricalcium phosphate into the soluble form, somewhat according to the following equation :—

$$Ca_3P_2O_8 + 2\ H_2SO_4 = CaH_4(PO_4)_2 + 2\ CaSO_4.$$

The monocalcium orthophosphate $CaH_4(PO_4)_2$ is the desired soluble compound formed; the calcium sulphate or gypsum serves to keep the mass dry and powdery. The presence of iron and aluminium not only consumes more sulphuric acid but also tends to make the phosphate 'revert' to the insoluble form by combining with the phosphate.

Ordinarily not all the phosphate is converted into the above form. Part is converted into $Ca_2H_2(PO_4)_2$ and part is left unchanged, so that the product is a mixture of the three phosphates. The following shows the average composition :—Gypsum 50%; Monocalcium orthophosphate $CaH_4(PO_4)_2$ 26·6%; Dicalcium orthophosphate $Ca_2H_2(PO_4)_2$ 2·4%; Tricalcium phosphate $Ca_3(PO_4)_2$ 2·2%; Silica 7%; Iron and Aluminium Sulphate 4·5%; Calcium fluoride 1·5%; Water 6%. Superphosphate by itself and on application to the soil has always a tendency to "revert" to the insoluble form, that is to say, the soluble $CaH_4(PO_4)_2$ becomes converted into less soluble forms like the di- and the tricalcium phosphates and also goes into combination with iron and alumina as insoluble phosphates. Nevertheless the phosphate continues to remain in its very finely divided condition capable of being taken up by plants, provided it is applied deep (3" to 4½") so as to be within the range of the roots. When iron and alumina are present as impurities or when the soil itself contains a large percentage of these, then the risk of reversion as phosphates of these elements and therefore of a reduced availability is greater. The addition of lime to such soils may counteract this tendency, as the reversion will be more as precipitated tricalcium phosphate. Large additions of green manure or cattle manure will also lead to better utilisation of the phosphate as it has been reported that the phosphorus enters into organic combination, in which form it is made use of better by plants.

As already stated, all surplus phosphates accumulate in the soil after the needs of the crop are met; it is insoluble in water and so, cannot be leached out. After the soil is well fertilised with phosphate it will be necessary to add to the soil as manure only such small quantities as may be removed or recovered in the crop, whereas, in the case of nitrogenous manures a large excess over such

intake will have to be applied, so as to make allowance for the losses.

Indian Rock Phosphates.—Special reference may be made to the phosphatic deposits in India, which, though comparatively insignificant, have the merit of being locally available. Deposits are said to occur to a small extent in Bengal (Hazaribagh) and in Upper India, but by far the most important is that found in the Trichinopoly District in South India. This is reported to be spread over an extent of some 60 square miles, and occurs in the shape of roundish or cylindrical masses the largest of which may be 10" in length. It is also practically a surface deposit being found scattered over the surface of the ground, or in small mounds or found imbedded in clay at a depth of some 10', exposed on the eroded sides of streams, and gullies. Recent surveys (1940) report however that the area of occurrence is 11 to 12 square miles and that the depth is up to 50' and total reserves of the material about 2,000,000 tons. At one time the nodules were mined and exported in considerable quantities by local firms which held mining leases.

The nodules are much mixed with sand and clay and in respect of the principal constituents have the following composition:—Phosphoric acid (P_2O_5) 23% to 27%; Lime (CaO) 38% to 47%; Iron and Alumina (Fe_2O_3 & Al_2O_3) 4% to 12%.

For utilisation as manure, very fine grinding (to pass a 100 mesh), composting with green manure, application along with green manure, composting with sulphur, conversion into superphosphates have all been suggested which apply of course to other rock phosphates as well. In the shape of finely ground powder the citrate soluble phosphoric acid has been found to be negligible, being only 0·38% (*Mys. Agr. Dept. Ann. Rep.,* 1905–06, p. 42). Mixing with green manures and other forms of composting afford some benefit but of course conversion into superphosphate, as in the case of other rock phosphates, is the most practical method and the matter has engaged attention for a long time ever since the discovery of the deposit more than some 60 years ago. The high percentage of iron and alumina necessitates however the use of too large quantities of sulphuric acid, which, a serious drawback as it is in any part of the world, is particularly so in India, where sulphuric acid has long remained an imported product. The sulphur needed for the acid being manufactured in India has also largely to be imported, and for such supplies of sulphur or sulphur ores available locally there is a large and serious competition from the numerous sugar factories. The only way therefore in which the material can be turned to manurial use would appear to be the new process of separating elemental phosphorus, in which the rock phosphate is mixed with sand and coke and heated to a very high temperature. Elemental phosphorus then volatilises and is oxidised into phosphoric acid for use thereafter in any manner desired, generally by absorption with ammonia to form ammonium

phosphate, the highly soluble double fertiliser. The difficulty regarding sulphuric acid can thus be got over, and the hydro-electric power now largely available in the country would appear to afford considerable scope for the new method.

Composition.—The following table gives the content of phosphoric acid in the various phosphatic manures:—

Phosphatic Manures

Name	Percentage of P_2O_5
Bones raw	18 to 23
„ steamed	31
„ char	26
„ ashes	35
Fish dried	1·7 to 7·6
Superphosphate	14 to 21
„ Concentrated	35 to 45
Trichi phosphate	25·5
Coprolites	24 to 34
Apatite (Canadian)	37·6
Ammophos A	46
„ B	20
Diammondiphos	53
Leunophos	20
Phosphazote	15
Nitrophoska	16
Leunophoska	10
Basic Slag	16 to 20

POTASH MANURES

Wood ashes of all kinds constitute the ordinary farm source of potash but on a commercial scale potash manures are supplied in the form of various salts of potash which are obtained mostly from the mines of Stassfurt and Alsace in Germany. The wood ashes and the ashes of all plant material generally and coal ashes supply the potash as potassium carbonate along with which is mixed considerable lime and a varying quantity of silica and ordinary earth. In addition to the ashes from the household kitchens and fireplaces, large quantities are also obtained from industrial plants where much firewood is burnt, or other fuel such as groundnut hulls, rice husks or sugarcane bagasse. Many other sources have been exploited periodically, especially during the two great wars when German supplies ceased. These comprise seaweeds, tobacco waste including cigar ashes, the mineral silicates, the water hyacinth and many plant wastes.

The commercial sources of potash are the crude minerals kainite, carnalite, sylvite, polyhalite, etc., either in the natural state or after refining, as sulphate of potash and chloride of potash. The highly nitrogenous potash manure, *viz.*, saltpetre or potassium nitrate is also an important source.

All potash manures are highly soluble in water and much care is needed in storage to prevent exposure to rain. They are for the same reason easily assimilable by plants and are also subject to loss by leaching from soils. The leaching is however not so great as may be expected, because potash manures react with the lime, soda and other bases in the soil and become fixed, though not to anything like the extent that the phosphates are. Considerable lime goes into solution as the result and is lost in drainage, leading to loss of lime from the soil.

The effect of potash manuring is influenced much according as it is applied as chloride (muriate) or as sulphate. The sulphate is a safer form to use, but it is costlier than the chloride. The latter proves injurious in many cases, such as for example the lowering of the burning quality of tobacco, of the crystallising out of sugar from syrups, and as is reported in some cases to the yield in the potato crop. In general it will be better to avoid it or to use it in mixture with sulphate, part as chloride and part as sulphate.

In Indian soils, potash manures seldom produce any response in the shape of increased yield; whether it may improve the "quality" of some is not definitely known, though it is highly probable. Certain malformations and abnormalities of leaves and stems in cotton, mulberry, beets and many *brassicas* are attributed to the lack of potash and are kept down by potash manuring. The intake of phosphates is also found to be favoured by potash manuring. It is a safe plan to include some potash manure in other ordinary manure mixtures, despite the fact that no increases in crop yields have resulted.

Composition.—The following table gives the percentage of potash (and of other plant food ingredients) in the various potash manures mentioned above:—

Potash Manures

Name		Percentage of		
		K_2O	P_2O_5	CaO
Cowdung cake fuel ashes	..	2·5	..	..
Paddy husk ashes	..	1·5	..	..
Lantana ,,	..	13·2	..	..
Bamboo ,,	..	5·4	..	..
Groundnut hulls ashes	..	6·45	..	..
Cigarette ,,	..	16·8	2·57	..
Eucalyptus wood ashes	..	23·8	5·9	27·4
Casuaritna wood ashes	..	14·0	1·4	36·0
* Tobacco stem ashes	..	36·0	2·6	15·0
Household ashes (Ceylon)	..	5·3 to 12·6	1·6 to 4·2	14·5 to 32·1
,, ,, (Bangalore)		·4 to 2·32	..	..
Orange skins ashes	..	27·4	1·23	..
Banana skins ashes	..	41·76	3·25	..
Potassium sulphate	..	44 to 51		..
Muriate of potash	..	52 to 58	..	..
Kainite	..	12·2 to 13·7	..	..
Potassium nitrate	..	26·8 to 40·4 (and from 3% to 13% nitrogen)		

*From *Ceylon Trop. Agrst.*, March 1946.

Lime as a Manure

Although lime is not a plant food which has to be supplied in the shape of manure, because no soils are without lime, still its application is found beneficial in practice and therefore necessary; in some cases it may be definitely called for. Its chief action in the soil is the flocculation of play and the improvement in texture physically. Chemically it corrects acidity in the soil, helps to fix potash added as potash manure, and promotes bacterial activity, being essential for proper nitrification. It is also said to help in making phosphorus in organic combination, soluble and available to plants. Very often there is a response in the shape of increased crop yields. Lime is removed from soils very much more, almost double, by legumes than by the grains and these will have to be supplied with lime as manure periodically.

Lime is applied as burnt or caustic lime, as slaked lime, or as carbonate in the form of ground limestone. It is also supplied by other manures incidentally, such as basic slag, superphosphate of lime, calcium cyanamide and ashes of various kinds. The application as ground limestone is the usual form, though air-slaked lime is equally common. The former is of course the safer. Both caustic and slaked lime soon become converted into calcium carbonate in the soil and the latter slowly changes into the somewhat soluble form of acid carbonate by the action of water and carbon dioxide in the soil. An ordinary dose is a ton of ground limestone per acre. The lime requirement is judged by a determination of the pH value of the soil, which will in most cases reflect the extent of such requirement (see also pages 44–46).

Soil Amendments

Somewhat similar to the addition of lime to soils, many materials are applied to fields as soil improvers or amendments, in order to improve the physical condition of the soil and in some cases to add at the same time some plant food elements also. Ordinary river sand, silt and clay from tank bottoms, fresh red earth, manurial earths from old village sites, all belong to this category. They are greatly esteemed and the improvement in the physical condition of the soil is very marked. Of course the materials are chosen suitably, such as sand for heavy soils, red earth and tank silt for the lighter loams, clay for sandy soils, and the manurial earths for both loamy and clayey soils. The practice is well known but deserves wider adoption.

An interesting method is what is known as "paring and burning"; this consists in scraping the top layer of certain soils, piling the material and burning it and then spreading it on the field to be ploughed in. This is followed in some parts of England and the treatment effectively corrects the stiffness of clayey soils making them more easy of drainage. Some of the mineral plant foods also

become more available, but it is destructive of the organic matter and wasteful of nitrogen. To a small extent the practice can be seen in the paddy fields of the Mysore malnad and in a slightly modified form in the system called "rab" burning. This latter method consists in piling up brushwood, dried cowdung and scrapings of the soil and burning the pile, and then spreading the burnt earth and ashes as manure, generally for paddy nurseries. Firing of the black cotton soil and its application to cotton is reported to have increased the yields of the cotton even up to 25%.

THE LESS IMPORTANT PLANT FOOD ELEMENTS

Though nitrogen, phosphoric acid and potash are the essential plant foods which are supplied in the shape of manures, there are some other elements also, which though ordinarily present in soils may sometimes be absent. As the result of such absence, crops on such soils suffer from peculiar maladies. These can be cured by the application of substances containing the element concerned and such abnormalities therefore somewhat resemble the "deficiency" diseases. These elements are magnesium, manganese, iron, zinc, copper, boron, sulphur, cobalt and molybdenum. The lack of these lead to the following defects :—

Magnesia.—Deficiency leads to a curious discolouration of the leaves resembling chlorosis and defoliation, especially in cotton and some legumes.

Manganese, Iron and Zinc.—Deficiency leads to chlorosis, which can be corrected by spraying with solutions of the sulphates. The addition of potassium permanganate or of manganese dioxide in minute quantities is also reported to increase yields, but this effect is attributed to the oxidising action of these compounds.

Copper.—Deficiency leads to die-back disease, and small applications to the soil and even sprays of copper sulphate in the form of Bordeaux mixture lead to increased yields in certain cases.

Boron.—Is toxic to plants but in very minute quantities can stimulate growth in plants which may have suffered from boron deficiency.

Sulphur.—Deficiency in rice soil leads to chlorosis, reduction in height of plants, failure to reach maturity and a reduced yield ; the condition can be remedied by applications of sulphur to the soils. In certain sheep pastures sulphur deficiency leads to interference with the normal growth of wool, just as a deficiency of lime and phosphorus leads to weak bones in animals on such pastures. The leaf crinkling due to lack of potash has already been mentioned.

Cobalt, Molybdenum.—The lack of these elements in pastures and therefore in the grass grown thereon has been found to cause special wasting diseases and nervous disorders in the cattle grazed on them.

These are given only as illustrations of the effect and use of these special elements (to which the name 'trace' or 'micro' elements is sometimes applied). Their use should be resorted to only when all the well-known factors of growth have been examined and excluded, and not at all as a matter of course. In the case of fruit crops, the use of some of these 'trace' element containing compounds is assuming some practical importance, especially in the treatment against diseases such as "chlorosis". The application is usually in the shape of a spray over the leaf surface by means of ordinary spray pumps or machines, but sometimes curious special methods such as driving an iron, or galvanised iron, nail into the stem, of injecting solutions into the inner bark, or of filling holes drilled in the stem with powders containing the particular element, are also resorted to.

CHAPTER XII

MANURING IN PRACTICE

THE main and the ultimate object of all manure studies is to find a reliable answer to the practical question, as to what manures should be used for particular crops and soils and in what quantities. Despite numerous experiments and much research, the question still remains very difficult to answer in a satisfactory manner and within a reasonably short time. For practical application within somewhat wide (or very wide) limits, the kinds and quantities of manures required for various crops have been determined and are available for practical guidance, if not for direct use. Before going into these data, it will be useful to briefly refer to the methods adopted in this all-important line of investigation.

The method of approach is broadly two-fold, *viz.,* (1) Chemical or laboratory experiments, and (*ii*) Cultivation experiments.

I. Chemical

1. The chemical analysis of soils and especially the determination of the 'available' plant foods by the Dyer method, gives some indication of the requirements but it is not always that this corresponds with the actual needs in practice, because, it is found that many soils contain sufficient stores of even available plant foods which can last for some crop seasons. It is only in the cases where a distinct deficiency is revealed that the information becomes of immediate practical use, but this is rather exceptional. Nevertheless the method is a valuable one and may in time be much improved, so as to make it applicable to all cases.

A SIMPLE METHOD OF CHEMICAL SOIL TESTING

2. It is interesting to note that a simple and practical system, which is a variant of the above chemical method, has been developed and a soil testing kit designed, which can be used on the field itself. The fertility level of the soil in respect of the plant nutrients is assessed on the spot, without the need for any laboratory, or other time-consuming method or apparatus. The method is based upon the colour changes produced in a water extract of the soil, by certain reagents which are special to this method. Depending upon the intensity or tint of the colour developed, the content of the particular plant food in the water extract which is the fertility level of the soil in that plant food is classed as high medium or low, without the trouble of making any quantitative estimation of the plant food. The method obviously relates to the fertility level for immediate cropping, in other words, to its "available" plant foods, and not to its potential value as may be judged by its total plant foods.

The method tests the soil in this way for ammonia, nitrates, phosphorus, potassium, calcium and the soil reaction, besides some others like iron, manganese, magnesium, sulphates and chlorides. The field testing kit is provided with the necessary solutions for the various tests, together with the few other requirements, and under the name, "the Simplex Soil Testing Kit" is described and full instructions given in the publication, *A Practical System of Soil Fertility Diagnosis,* by C. H. Spurway and K. Lawton, of the Michigan State Agricultural College, U.S.A., conducted with all the safeguards, and instructions described, it is claimed that the findings are reliable and useful for practical application.

3. The analysis of the whole crop, *i.e.,* all the above ground parts, *viz.,* stems, leaves and fruit or grain, will give information as to the quantities of plant foods which a good crop may be expected to remove from the soil. It is obvious that this quantity at least (or increased by any desired percentage) of the different plant foods will have to be supplied in the shape of manure, year after year. With the data furnished by the above two ways, an answer may be attempted, which may at least form the basis on which cultivation experiments may be planned.

4. The power to evolve carbon dioxide from the organic matter in the soil by the agency of bacterial action, as measured by the quantity of the gas given off under properly controlled incubation, is utilised in one method to determine the manurial needs and the level of fertility of different soils. This method has recently been modified, so that the bacterial activity as altered by the addition of one or more plant foods, is determined and from the results, conclusions are drawn as to what particular plant food or plant foods the soil is in need of (*vide* paper by S. V. Desai, *Proc. Ind. Sc. Cong. 33rd Session,* Part IV, page 34). The old method, with the modifications now suggested, may, if the claims are fully verified, prove very useful in furnishing an answer to such manurial questions within a short time.

II. Tests by the Growing of Crops

These tests range from those (1) which take only a few hours to conduct, (2) through those taking a few weeks to, (3) those requiring a regular full crop season to complete, such as pot culture or field cultivation experiments. In tests of the first type portions of the tissues of the plant growing in the particular soil are tested by rapid colorimetric methods, which reveal if the soil is supplying a sufficiency of nitrogen, phosphoric acid and potash or not.

Reference may be made to the method of judging nitrogen deficiency in cotton, by cutting out discs from the leaves, extracting them with boiling water and testing the extract with osmic acid, a quick method which may perhaps be applicable to other crops also. The electrical conductivity of water extracts of soils is also used to determine the level of fertility of the soils tested. The higher the

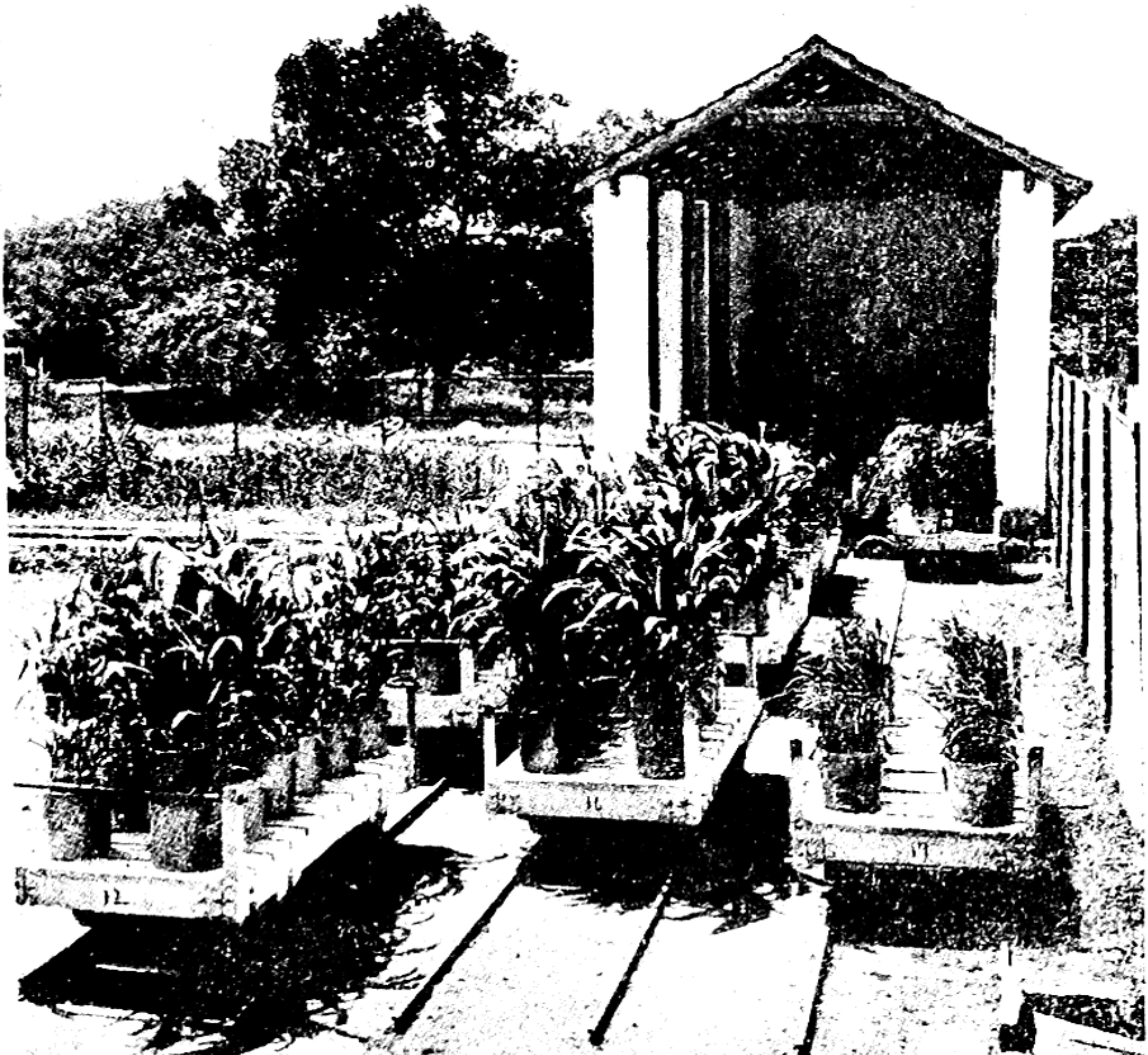
conductivity, the more fertile the soil is taken to be, especially if the conductivity should continue to rise rapidly as the extraction is prolonged. A low conductivity on the other hand, which also remains low on prolonged extraction, shows a low level of fertility. Of course the method does not give any information as tc what particular plant food or foods such a soil may be wanting in.

The method of judging the nutrition requirements of the soil for any particular crop by the analysis of leaf or plant tissue has in fact been much developed in recent years and in view of its quickness is frequently resorted to in advisory work. An even simpler method consists in judging requirements by a mere inspection of the growing plant, as the outward appearance of the crop in respect of leaf shape, leaf colour, malformations and other abnormalities are known to be correlated with a deficiency or sometimes excess of particular plant foods. The diagnosis is more often in respect of deficiencies, and, in any case, is only qualitative in character. Such diagnosis has particular reference generally to the trace elements. The methods are based of course upon the tendency of plants to reflect deficiencies or excesses of plant nutrients in outward behaviour or character.

A method somewhat similar to this foliar diagnosis is that of 'injection' diagnosis, in which particular plant foods are supplied by injecting suitable solutions containing such plant food into the plant tissue and watching the response. If the latter is striking, then obviously the soil is not supplying enough of that plant food, which has therefore to be supplied in the shape of manure.

The Neubauer Method.—In the second type of tests, comes the 'seedlings test' devised by Neubauer of Dresden. In this method rye is grown in the soil concerned in small wire baskets or glass boxes and the seedlings are analysed after they have grown for 18 days, and from the quantities of phosphoric acid and potash taken up from the soil, its manurial needs in respect of these two constituents are estimated. The results are reported to accord well with field trials and that as a quick method for practical purposes, Neubauer's method is much commended.

Pot-Culture Experiments.—The pot-culture and field experiments take months to complete but may be regarded as more applicable in their results. Among pot-culture experiments, the method of Wagner (of Darmstadt) has much to be said in its favour. According to Wagner, the plant food requirements for a maximum crop are determined by actual pot-culture trials, *i.e.*, by adding increasing doses until no more increase in yield is obtained: for field cultivation in the soil concerned, the annual addition of nitrogen to be made is taken to be from 50% to 100% more than this quantity, so that allowance is made for the losses usual in the case of nitrogenous manuring; this manuring is also to be given in two or three instalments as and when required, judged by the appearance of the crop. With regard to phosphoric acid, the quantity required for a



The Pot Culture House of the Mysore Department of Agriculture in which manurial experiments by this method are carried out.

Mys. Agr. Dept.

maximum yield is likewise determined by actual trial; the soil content of phosphoric acid is then brought up to this level by a heavy application of phosphatic manure and then the yearly application is the quantity which the crop actually removes from the soil. A like process is adopted in the case of potash. Wagner's method may be regarded as the best approximation to practical requirements.

Field Experiments.—The actual field experiment on the soil concerned comes next; this of course is the one most directly applicable to the desired farm or situation, and with the data obtained by the quicker methods taken for guidance, can be made as accurate as may be possible in practice. They have to be repeated over more than one crop season in order to eliminate or allow for seasonal variations, although other interfering factors can be provided against by a suitable arrangement of the plots for a statistical interpretation of the results. The actual methods of conducting these experiments and the technique involved are beyond the scope of this book and special works will have to be consulted.

Rate of Intake of Plant Foods

The different plant foods, nitrogen, phosphorus and potash, do not appear to be taken up by crops at the same rate in all the stages of their growth; a larger percentage of the plant food applied is taken up at one stage than in another. For example, in the case of rice, both potash and nitrogen are absorbed most in the first 3 months, after which the potash falls off and nitrogen shoots up, and phosphorus, magnesia and lime are taken up only to a negligible extent throughout, with a slight rise in the 5th month (van Rossem's experiments in Buitenzorg, quoted by A. Jacob and V. Coyle, in the *Use of Fertilisers*). In sand culture experiments in Bangalore with ragi and with cotton, it has been found that by far the largest bulk of the three plant foods is taken up in the first 10 or 12 weeks, *i.e.,* by the flowering stage and that in the case of the cotton the intake of nitrogen almost comes to a close. In the case of both crops material proportions of phosphorus and potash continue however to be taken up in the later stages also (*Mys. Agr. Dept. Ann. Rep.,* 1935 and 1936). In the case of sugarcane it is stated that the absorption of potash is very great in the later stages of the growth. Whether in all these cases, it will be of advantage to apply the different plant foods at different appropriate stages, and especially part of the prosphatic and potash manures at a later stage, is a point worth examining. It cannot be very difficult in practice to apply them when the crop has made considerable growth, especially so with potash manures which can be introduced along with the irrigation water (in the case of irrigated crops).

Use of Radioactive Isotopes

It is interesting to note in this connection that by the use of radioactive isotopes of the plant food elements in the soil nutrients or nutrient solutions, it has now become possible to trace the progress

of the absorption, the stage when it begins, what course it takes, when it is most active, in what particular part of the plant it lodges and so on, with the help of Geiger counters which detect radioactivity. This new technique will therefore throw much light on this important practical question of the time when some of these can be applied with the greatest benefit.

"Dominant Ingredients" in Manures

Mention may be made in this connection of the "dominant ingredient" theory of the French Chemist Ville. According to Ville (and this is confirmed by others also) crops can be classified into four classes depending upon the plant food to which the crop responds best, and such plant food then becomes the 'dominant ingredient' for the particular crop. In actual manuring a larger proportion of this plant food is added than of the others. Although among Indian crops, nitrogen is mentioned as the 'dominant' ingredient for all grain crops and grasses, phosphoric acid for sugarcane and cotton, potash for tobacco and lime for all legumes, it must be pointed out as has already been done, that under Indian conditions all crops have been found to respond to nitrogen best and that the other ingredients come only far behind.

Some General Principles

Innumerable manurial trials on a field scale have been conducted both in India and outside to determine the manurial requirements for particular soils and crops, the results of which can in a strict sense be applicable only under the particular local conditions. Nevertheless within wide limits certain general principles may be taken as a basis and to these attention may now be drawn.

1. *The Need for Organic Matter.*—As a general rule and wherever possible soils should receive a basal dressing of cattle manure. This may be supplemented by the application of green manure or the latter itself may be made the source of the organic matter if cattle manure is not available, and may be grown in the field and ploughed in. A normal basal application of cattle manure will be about 5 tons per acre but if supplies are limited then this dose may be reduced and the supply divided evenly over the whole area or the latter may be divided into blocks which may be manured with the full dose in rotation.

2. All concentrated and quick-acting manures are to be applied generally to the young standing crop and in two or more doses. The time of application should be such that the field has enough moisture, during light showers or where irrigation can be given. In tracts of very heavy rainfall, the application should be made after the season of heavy downpours is over and when only light showers prevail or are expected.

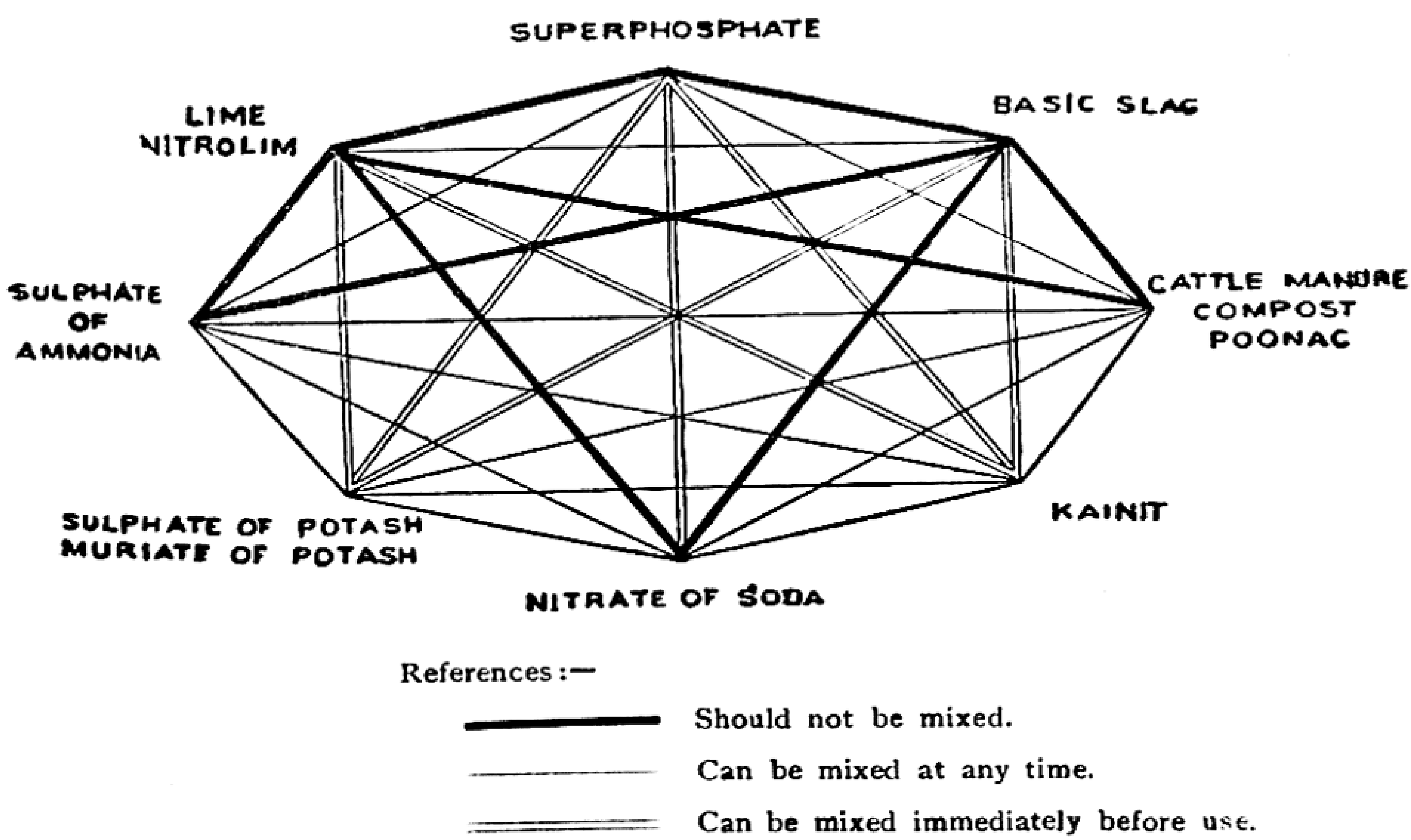
3. The ordinary dose of the different plant foods to be applied may be fixed roughly at the following rates, particular ones being

increased when found necessary or profitable; nitrogen such that from 25 lb. to 50 lb. may be supplied in the manure, except in the case of a long season crop like sugarcane when it may be increased up to 150 lb. per acre; phosphoric acid doses may be given from 20 lb. to 35 lb. per acre; and potash from 15 lb. to 25 lb. per acre. The manures selected so as to contain these quantities of the plant foods (in all of them taken together) may be a mixture comprising both quick-acting and moderately quick-acting kinds, the latter being used preferably at the beginning and the former when the standing crop has made fairly good growth. This course will also effect a saving in the total cost of the manure.

4. The soil may be tested for lime requirements and if the need is indicated, then a dose of not less than 1 ton of ground limestone per acre may be applied and repeated if necessary once in 3 years.

5. In purchasing manures, the percentage of the plant food content should be taken note of along with the price; the 'unit' value of the plant food calculated, and the one in which this is lowest (consistent with availability) purchased.

6. The mixing of the different kinds of manures should be such that no loss of ammonia takes place, that the mixture does not set hard on mixing and is more or less in a dry powdery condition fit for spreading or drilling. The following diagram will be found useful in this connection.



Mixed fertilisers for different crops according to their own formulas are put out for sale by fertiliser companies and these are generally mixed in the correct way; the ingredients are well ground and the mixture is made in special mechanical mixers and is therefore more thorough and uniform than can be made on the farm. If mixing is attempted on the farm, then the proportions can be varied according to any desired formula. The ingredients should be in a well-ground condition and for mixing, they should be spread on a stone or other hard floor in square alternate layers about 6" thick in successive units one above the other and should then be thoroughly shovelled over from end to end more than once until the mixture is thorough and uniform.

7. Cattle manure and such bulky manures may be ploughed in or applied in furrows and covered over by ploughing the adjoining furrow or dug into the soil. Easily soluble manures like sulphate of ammonia, nitrate of soda or sulphate of potash should be given as a top dressing or lightly forked in, sprinkled and lightly stirred into the soil. Oilcakes may be applied in shallow furrows or merely as a top dressing and forked in. Superphosphates should be dug in a little deeper than these, so that the fixation of the phosphate will take place near to the feeding roots. The various other phosphates like ammophos should be treated likewise. Application on a large scale can be made to approximate to the above requirements as far as possible but in small cultivation it will be possible to apply the manure so as to make it lodge where it will be of the greatest benefit to the crop, nearest the area where the feeding roots can be found to spread.

Is Cattle Manure Indispensable?

In this connection it may be of interest to make reference to the question whether cattle manure is indispensable. In recent years there has been a controversy going on regarding the so-called harm being caused by the application of artificial chemical manures and stressing the need for raising crops *only* with cattle manure. That all the cattle manure which can be had should be carefully husbanded and used as manure admits of no doubt and in practice it is invariably done. The exception is only the colossal folly of using it as fuel prevalent in many parts of India, but this is because people are forced to do so on account of the scarcity of ordinary firewood, charcoal or other fuel, and it may be expected that as the situation improves in regard to fuel supply this practice will gradually disappear. Every effort is in fact being made to save this material for manurial use and no one is more concerned with the depletion of manure in this way than the farmer himself, who is forced by circumstances to use some of it to eke out his supply of fuel.

When however it is alleged that farm-yard manure alone should be used and that chemical manures should not be used, it is difficult to accept the claim, in view of the enormous and well-recognised

increase in crop yields which have followed the use of chemical manure all over the world, since these began to be used. It is claimed that the 'quality' of the grain raised with cattle manure is superior and that it promotes growth better than grain raised under chemical manures, which is apparently based upon a set of experiments conducted in South India which so far as is known has not been as widely repeated and confirmed as its importance requires. It is also stated that produce raised with farm-yard manuring has many health-giving properties, confers freedom from disease in the growing crop and so on, as against produce raised with chemical manures—none of which can be said to be based upon well-controlled experiments. Although it is quite possible to raise crops with chemical manures alone, in practice cattle manure and organic manure of other kinds are generally applied to the extent possible and some form of organic matter always occurs in cropped land in the shape of the crop residues at least. In some form or another organic matter always accrues to the soil and a case can never be cited when such is not the case. The question in this sense becomes therefore only of academic interest. The world requirements of produce whether for food or as raw materials for the industries cannot be met, without resort to the use of chemical manures, whether as a most powerful ally for supplementing organic manure as in practice, or independent of it, if necessary. No farmer need be told that he should use all the farm-yard manure for that purpose; the need is on the other hand for a larger use of the chemical manures. Curiously enough, it is interesting to note, that those who raise crops by the new method of "hydroponics" or "soil-less culture" make the equally strong claim that they are able to raise very heavy crops of excellent quality, by the use of mineral or chemical nutrients alone, without cattle manure or other organic matter in the nutrient solutions.

At the same time, it should be noted that the excreta of animals possess properties which have been discovered in recent years and which are attributed to certain "hormones" present in them. The urine of pregnant cows, for example, has the property, if injected into the system of bulls, of improving their fertilising power and making them more efficient as breeding bulls; growth-promoting hormones and root-stimulating or developing hormones, are also to be found in the urine and dung of animals (including humans), as well as the power of suppressing or killing certain bacteria and of promoting the growth of others. Though somewhat mysterious at present, it is not unlikely that eventually the active substances concerned will be isolated and probably synthesized.

In view of this special property of cattle manure, it will be advisable to supplement artificial manures wherever possible with some amount of cattle manure however small it may be, making the latter a kind of small basal dose. As cattle manure is always found insufficient, in practice it may be arranged that the estate or holding

is divided into three or four blocks, each of which is given cattle manure only once in that period by rotation. In the alternative and in the case of annual crops, the cattle manure may be given to that crop in the rotation which is the most valuable or which will respond best by a high yield without detriment to quality.

The difficulty can also be overcome to some extent by adopting the method of composting by using the small available quantity of cattle manure as the activating agent for the decomposition of the large bulk of composting materials. Such a method affords a supply for covering a larger area, which to a considerable extent possesses the same special property of cattle manure. Composting in this way affords indeed the best method for securing this end.

Manures in Hydroponics

There are some interesting practical features in the application of plant nutrient salts in the hydroponic method of growing crops, to which reference may be made, principally because the crop yields which are reported are truly remarkable, and the quantity or dose per acre is not so high as such yields may indicate. These are: (1) that no organic manure of any kind is used, all the plant food elements being supplied in the form of inorganic or mineral salts in readily available condition; (2) the nutrients are applied in small doses at frequent intervals of 1 week or 2 weeks; (3) the nutrients furnish a full complement of plant foods, including even the trace elements. In the Kalimpong Research Centre in India, the nutrient solution contains the following: Nitrate of Soda 4½ oz.; Superphosphate 3 oz.; Calcium Sulphate 2 oz.; Potassium Sulphate 1½ oz.; Magnesium Sulphate 2½ oz.; Trace elements ¼ dram; or a total of 13½ oz. dissolved in 100 gallons of water. Once a week 200 gallons of this solution (which contains 27 oz. of the nutrients) are applied to a hydroponic trough with a surface area of 1,000 sq. ft. For a crop of about 2½ months like wheat or maize, this will work out to about 600 lb. of the mixture per acre, which though liberal cannot be called a very high dose. The yield, however, has been reported to be 4,100 lb. per acre for wheat and 5,600 lb. for maize; both are truly extraordinary figures although it was realised only in the small-scale trough culture. The above dose is for the dry season, a slightly changed dose is used during the monsoon season. The trace element mixture comprises zinc sulphate, manganese chloride, boric acid, copper sulphate and iron sulphate, made up of 3, 9, 7, 3 and 10 drams respectively, and ¼ dram of the mixture is taken up for 100 gallons of water. It is reported however that in small-scale household hydroponics work, there is no need to add any trace elements specifically, because these occur as impurities in the ordinary commercial fertilisers. For a detailed account of the work and procedure in practice, Bulletin No. 1 of the Station may be consulted (see also page 25).

Manure Mixtures for Particular Crops

Subject to all the limitations indicated in the foregoing pages to suggestions regarding the manurial doses for various crops and more or less as a helpful basis which may be improved upon by actual experience under particular local conditions, the following recommendations are appended. More should not be expected from them than is warranted by the highly qualified applicability of the formulæ :—

Rice.—On a basis of 5 cartloads of cattle manure (or 5,000 lb. of green manure) worked in the puddle, a mixture consiting of 100 lb. of sulphate of ammonia and 120 lb. of superphosphate is to be given half at transplanting and half at the first weeding (Mysore). Japanese intensive cultivation manuring comprises a mixture made up of 100 lb. to 200 lb. sulphate of ammonia, 250 lb. to 450 lb. of superphosphate or 200 lb. to 350 lb. of bonemeal and 50 lb. to 100 lb. of sulphate of potash. Hawaiian experiments favour a mixture of 150 lb. of sulphate of ammonia, 225 lb. of superphosphate and 120 lb. of sulphate of potash.

Wheat.—In irrigated cultivation a mixture containing from 100 lb. to 200 lb. of sulphate of ammonia, 200 lb. to 400 lb. of superphosphate and 50 lb. to 100 lb. of muriate or sulphate of potash is considered a general standard. On the red loams (not black cotton soils) and under irrigation, with a basal dose of 5 cartloads of cattle manure, a mixture of 50 lb. to 75 lb. of sulphate of ammonia, 75 lb. to 100 lb. of superphosphate (Mysore).

Ragi (Dry Land).—With a basal dose of 5 cartloads of cattle manure, about 200 lb. of groundnut cake powder or a mixture of 50 lb. of sulphate of ammonia and 40 lb. of superphosphate, to be applied at weeding time. For irrigated ragi, the dose may be increased by 50%.

Sorghum and the Millets.—A mixture of 50 lb. of sulphate of ammonia, 100 lb. to 200 lb. of superphosphate, and 50 lb. to 100 lb. of sulphate of potash, for irrigated intensive cultivation.

Maize.—A mixture of 90 lb. to 125 lb. of sulphate of ammonia, 150 lb. to 250 lb. of superphosphate, and 75 lb. to 150 lb. of sulphate of potash.

Cotton.—On the black cotton soils, about 500 lb. of groundnut oilcake and on ordinary red loams and under irrigation, about 1,000 lb. of groundnut oilcake. In Egypt a mixture of about 424 lb. of sodium nitrate, 212 lb. of superphosphate and 160 lb. of sulphate of potash is used.

Sugarcane.—With a basal dose of 20 cartloads of cattle manure (or some 3,000 lb. of green manure) a mixture of 5 cwt. to 8 cwt. of sulphate of ammonia, 10 cwt. of groundnut oilcake, 1½ cwt. of superphosphate, and 1 cwt. of sulphate of potash (Mysore).

Potatoes.—With a basal dose of 15 cartloads of cattle manure, a mixture of 1 cwt. of sulphate of ammonia, 1½ cwt. of superphosphate, and 1½ cwt. of sulphate of potash (Mysore). On the Potato

Farm in the Nilgiris a much heavier dose, *viz.*, a mixture of 500 lb. of groundnut oilcake, 200 lb. of sulphate of ammonia, 350 lb. of steamed bonemeal, 336 lb. of superphosphate, and 224 lb. of sulphate of potash is recommended. Elsewhere (South Africa) a mixture of 300 lb. of sulphate of ammonia, 900 lb. of superphosphate, and 200 lb. of sulphate of potash is used.

Tobacco.—For nurseries: 1 lb. of a mixture containing 30 lb. of sulphate of ammonia, 15 lb. of concentrated superphosphate, and 16 lb. of sulphate of potash, for an area of 4 sq. yards. For the field itself a mixture of 100 lb. of groundnut oilcake, 80 lb. of sulphate of ammonia, 150 lb. of superphosphate, and 60 lb. of sulphate of potash per acre (Mysore). Another standard mixture is one containing 50 lb. to 100 lb. of sulphate of ammonia, 150 lb. to 250 lb. of superphosphate, and 100 lb. to 150 lb. of sulphate of potash of over 90% purity.

Chillies.—On a basal dose of 10 cartloads of cattle manure, oilcake at the rate of 10 cwt. to 15 cwt. or a mixture of 2 cwt. of sulphate of ammonia, 4 cwt. of superphosphate, and 1 cwt. of sulphate of potash. Another mixture recommended is 2 cwt. of groundnut cake, 3 cwt. of superphosphate, and 1½ cwt. of sulphate of potash.

Onions.—A mixture of 200 lb. to 400 lb. of sulphate of ammonia, 600 lb. to 900 lb. of superphosphate, and 200 lb. to 300 lb. of sulphate of potash.

Brinjals (Egg Plants).—A mixture containing from 400 lb. to 600 lb. of sulphate of ammonia, 900 lb. to 1,300 lb. of superphosphate, and 350 lb. to 500 lb. of sulphate of potash (Japanese experiments).

Ginger.—A mixture containing 200 lb. to 250 lb. of sulphate of ammonia, 450 lb. to 750 lb. of superphosphate, and 150 lb. to 250 lb. of sulphate of potash (Japanese experiments).

Plantains.—Groundnut oilcake or castor oilcake at the rate of 10 cwt. to 15 cwt. at the third month, together with a mixture containing 2 cwt. of sulphate of ammonia, 3 cwt. of superphosphate, and 1 cwt. of sulphate of potash (Mysore).

Cabbage, Cauliflower and Similar Vegetables.—A mixture containing from 400 lb. to 600 lb. of sulphate of ammonia, 900 lb. to 1,300 lb. of superphosphate, and 250 lb. to 350 lb. of sulphate of potash.

Tomatoes.—A mixture containing from 250 lb. to 400 lb. of sulphate of ammonia, 450 lb. to 650 lb. of superphosphate, and 200 lb. to 300 lb. of sulphate of potash.

Cocoanuts.—A mixture containing 50 lb. of compost manure, 1 lb. of bonemeal, 1 lb. of concentrated superphosphate, 2 lb. of muriate of potash, and 1 lb. of common salt per tree in bearing (Mysore). Another mixture is one containing 150 lb. to 200 lb. of sulphate of ammonia, 250 lb. to 350 lb. of bonemeal, and 150 lb. to 200 lb. of muriate of potash, per acre of 50 trees.

Castor.—A mixture containing 100 lb. to 200 lb. of sulphate of ammonia, 200 lb. to 400 lb. of superphosphate, and 100 lb. to 150 lb. of sulphate or muriate of potash.

Gingelli.—A mixture containing 125 lb. to 250 lb. of sulphate of ammonia, 150 lb. to 250 lb. of superphosphate, and 50 lb. to 100 lb. of sulphate or muriate of potash.

Coffee.—For heavy bearing areas, a mixture made up of 150 lb. of groundnut oilcake, 40 lb. of sulphate of ammonia, 76 lb. of concentrated superphosphate, and 60 lb. each of sulphate of potash and muriate of potash; for evenly bearing areas, a mixture of 100 lb. of groundnut oilcake, 40 lb. of sulphate of ammonia, 60 lb. of concentrated superphosphate, and 40 lb. each of sulphate and muriate of potash. An application of lime at the rate of 1 ton of slaked lime per acre once in five years (Mysore).

Arecanuts.—Cattle manure at the rate of 10 cartloads an acre is to be applied and then covered over with earth and green leaves at the rate of 5 cartloads per acre. Every third year a mixture containing 200 lb. of groundnut cake, 80 lb. of sulphate of ammonia, 200 lb. of concentrated superphosphate, and 300 lb. of sulphate of potash is to be applied in addition (Mysore).

Orange Trees.—For trees in bearing, a mixture containing 200 lb. to 250 lb. of sulphate of ammonia, 400 lb. to 500 lb. of superphosphate, and 200 lb. to 300 lb. of sulphate of potash per acre.

Apples.—A mixture containing 80 lb. to 100 lb. of sulphate of ammonia, 300 lb. to 500 lb. of superphosphate, 100 lb. to 300 lb. of bonemeal, and 150 lb. to 250 lb. of sulphate of potash per acre of 100 bearing trees.

The quantities given are all per acre doses. A small basal dose of cattle manure will be a great advantage in all cases. The formulæ, other than those relating to Mysore or the Nilgiris, have been extracted from the *Use of Fertilisers,* by A. Jacob and V. Coyle.

SEEDS AND SOWING

THE quality of the seeds sown is an important factor in crop yields and great care has to be taken in selecting seeds of the best quality. Much disappointment and loss may be avoided if the necessary attention is paid at the proper time to this selection. Seeds intended for sowing should satisfy the following requirements :—

(1) They should belong to the proper variety or strain of the crop which is proposed to be grown; (2) They should be clean and free from obvious mixtures of other seeds; (3) They should be mature, well developed and plump in size; (4) They should be free from obvious signs of age or bad storage such as mouldiness, insect attacks, bad smell, etc.; (5) Above all they should have a high germinating capacity.

Each of these requirements may now be dealt with in some detail.

1. *Proper Variety.*—Where the farmer obtains seeds from his own fields by reserving a portion of his own produce for seed purposes, this condition is easily assured, but where seeds are purchased from outside sources there must be a guarantee in this respect, such as may be had from reliable suppliers whether merchants or growers. The risk in getting seed from doubtful sources will arise from the variety or strain supplied differing in (*a*) yield of grain or straw. (*b*) habit of growth, *i.e.,* whether tall or dwarf, (*c*) nature and quality of the grain, (*d*) unsuitability to season or tract, and (*e*) even susceptibility to disease. The greatest and common danger arises in respect of (*d*), *viz.,* unsuitability of season. Varieties which are supplied as short duration ones prove of long duration in the new tract or varieties suited to one particular season are supplied as suitable for another season and prove unsuitable. Both these are common in the case of rice. Where the identity of a variety cannot be made out by its appearance alone, then a great deal of caution has to be exercised before accepting the seeds for sowing. It will be advisable in the case of outside supplies for the farmer to satisfy himself by an inspection of the crops in the village from which seeds are eventually to be bought, if such an inspection can be managed. Varieties will have to be derived from villages or tracts where that variety alone is grown; this will reduce the variation which may otherwise occur due to cross-fertilisation with other varieties, in the case of all crops in which much cross-fertilisation takes place. Fortunately in the case of the Indian grain crops there is not much danger in this respect. Sometimes cross-fertilisation is purposely induced in crops intended for seed in order to secure 'hybrid vigor'; the most outstanding example of such practice is the raising of 'hybrid corn' or maize in the U.S.A. Seed raising by special

agencies who may be expected to adopt all the necessary technique has not yet come into existence in India, with perhaps the sole exception of the Indian Leaf Tobacco Co., who raise seed for the Virginia cigarette tobacco called Harrison's Special, on a very large scale.

2. *Freedom from Admixture of Other Seed.*—Seeds whether from the farmer's own crop or purchased should be free from admixture of other seeds and also clean. If the farmer is growing any particular variety of grain, say, some selection supplied by the Agricultural Departments, then it will be advisable firstly to rogue out obvious mixtures in the standing crop itself and secondly to thresh this crop first and take up the others only afterwards; in this way it will be possible to eliminate mixtures and maintain the purity of the selection.

The commonest mixture comes however from the seeds of various weeds, many of which mature seeds about the same time as the crop and are harvested and threshed along with it. Such mixture, if sown, obviously brings up a huge growth of weeds in the field, all the care bestowed upon the preparation of the soil goes to waste and more frequent and thorough weeding involving additional labour becomes necessary. There is a reduction in the yield and in the quality of the produce due to the mixture of weed seeds.

The seeds of some kinds of weeds differ in size from the seeds of the crop and can be removed by appropriate sieves; others differ in weight and can be winnowed out; both methods should be adopted and the seed freed as thoroughly as possible from the mixture. With some weed seeds however it is not practicable to exclude them and the best course will be not to use them for sowing. The important maxim to remember is to avoid all possible sources of weed seeds by efficient methods of weed control. These methods are dealt with separately in the Chapter "Weeds and Weed Control".

Other foreign matter such as earth or gravel, chaff, bits of wood or dry leaf, etc., though not directly harmful, are still indications of poor quality in other respects and should be looked upon with suspicion. When a farmer stores seeds from his own produce, care is usually taken to clean it free from such impurities.

3. Seeds should be well developed, plump and free from immature or shrunken grains. Large well-developed seeds have a larger amount of reserve material to draw upon in their endosperm and the seedlings from them possess more vigour. The larger seeds are also as a rule heavier in weight and in most cases heavier seeds lead to a better crop than lighter seeds. It will, in fact, be advisable to select the heavier portion of the seeds from the bulk for sowing purposes, rather than to sow the bulk. The selection can be effected generally by suitable sieves or by stirring the seeds in plain water or water made heavier by dissolving common salt in it to saturation. A mixture with immature or shrunken seeds is of course easily made

out from the appearance, and any seed lots should therefore be rejected if they are found to contain a large percentage of such seeds.

In the ordinary methods of collecting seed for storage, the farmer uses such methods as will effect a separation of the lighter grains. When grain is winnowed by letting it down from a height when the wind is blowing, grain meant for seed is taken from the quantity lying directly below the winnower, as the nearer they are to this spot, the greater is their weight than those farther away. Special apparatus is also in use for this method in the case of tobacco seed.

4. *Germinating Capacity of Seeds.*—This of course is the most important requirement in seeds. Seeds should possess a high germinating capacity, the higher the better. A cent. per cent. germination is of course the best and should be aimed at. If seeds with a low germinating capacity are sown, the mistake is found out only when it is too late to mend; the plants come up very thin, and bare patches may be many and serious. In bad cases the field will have to be ploughed up and resown. The correct season may however have passed, it may not be possible to replough the land, or the necessary further supply of seed may not be available. Even when the seed is not so bad as to require this extreme step, the thin stand and the bare patches will necessitate considerable transplanting of seedlings to fill up the gaps, or cause heavy weed growth and reduced yield, if not attended to in this way. Sometimes though the germinating capacity may not be very low, the uniformity and quickness of germination may not be up to the mark, and delayed and uneven germination is as bad as patchy germination. Such germination is also an indication of lack of vigour in the subsequent growth. Poor germinating capacity may be due to the age of the seed, immaturity or spoilage in the stack or storage, insect damage, mouldiness due to imperfect drying, etc. The outward appearance will give a sufficient indication of quality, in respect of all except age and seeds can be approved or rejected on that indication. In respect of age however this may not be possible always. Colour and smell may give some indication but not always.

Germination Test.—It is a safe practice and one which should invariably be adopted, and especially so in the case of seed derived from outside supplies, that a germination test is made before buying or using it for sowing. A random but representative sample of the seed should be taken and 100 seeds put out for germination over moist sand in a shallow saucer, covered and kept safe from ants, rats, etc., and moistened every day. The number of seeds which germinate from day to day should be counted and removed, and the total sprouting within 48 hours from the first sprouting (including the latter) may be taken as the percentage of germination. Some seeds may be delayed beyond this 48-hour period but should not be reckoned in judging the percentage, as both quickness and number

are important. If the seeds are good, then a 100% germination is obtained; but anything below 75% should be considered bad. If however one should be obliged to sow seeds with a lower percentage, then the necessary allowance will have to be made and the seed rate increased accordingly.

Age of Seeds and Germination.—The period of time or number of years during which the seeds of agricultural crops will retain their germinating capacity to the standard required for sowing varies with different crops. As a matter of curiosity it may be mentioned that tests made of seeds of known age from 25 to 135 years (by Becquerel) showed that some were viable up to 90 years; the maximum duration of vitality may be said to be 250 years! It is interesting to add that such longevity is found only in the legumes. Apart from this absolute persistence of life, as a rule the percentage goes down gradually from year to year with increasing age but after about 3 years (3 to 5 being considered the critical ages) it drops suddenly, going down to zero very soon, and this age gives therefore the maximum which may be allowed. This however is only of theoretical interest and it is only the period during which the germination does not go below 75% which is important agriculturally. This period in the case of many crops will not exceed 5 years, although there are exceptions like tobacco which is reported to keep good for many years.

The question as to how fresh the seeds have to be is also of practical interest. The seeds of certain fruit trees like jack, citrus and the Eugenias, for example, have to be sown immediately after removal from the fruit; the tea plant is another example in which the seeds have to be very fresh, although dry.

There are other seeds which require a certain period of dormancy before they can sprout or before they can be used as seed. This is not a serious matter in the case of most agricultural crops which have to be kept stored in any case until the next sowing season arrives. In exceptional circumstances it may become necessary to have recourse to the fresh seed itself for sowing purposes; then the question whether they will sprout at all and what interval of dormancy will be the minimum becomes important in practice. Many seeds like rice or ragi will sprout readily (in fact they may sprout in the earheads if they become wet with rain after harvest) but it is not known whether the crop raised from such seeds will grow and yield normally. The belief is common that it is not advisable to use such seed. The certain amount of maturity of the embryo goes on in the fresh seed which takes time to complete and germination therefore is likely to be delayed and patchy. It is believable therefore that yields may suffer. It is also possible that the vegetative period of such a crop may be unduly prolonged and that it may become a long-duration crop, the period usually spent in dormancy being transferred, so to speak, in part to the vegetative stage. There are however no definite experi-

mental data bearing on the point and it would be safe to follow the general practice of storing such seeds for the period between harvest and the next sowing season, *i.e.,* for about 6 months.

The viability of certain agricultural crop seeds have been studied by K. M. Sonanve and the result of this interesting study is given in the following table :—

Crop	Percentage germination in successive years												
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
Bajri (*Pennisetum typhoideum*) ..	94·5	93·6	89·1	87·0	61·2	33·1	41·7	5·8	0	2·0	0	0	0
Jowar (*Andropogon sorghum*) ..	89·7	90·7	90·8	84·5	79·1	83·7	67·2	46·5	0	0	7·2	0	0
Wheat (*Triticum sativum*) ..	97·6	98·2	97·3	99·1	98·1	67·8	44·6	5·2	18·1	·3	7·3	0	0
Maize (*Zea Mays*) ..	96·1	97·3	96·2	89·6	86·7	60·8	24·5	1·1	0	0	0	0	0
Tur (*Cajanus indicus*) ..	93·5	89·2	91·1	88·1	87·1	90·2	76·8	61·1	23·7	1·2	1·2	1·1	0
Mung (*Phaseolus mungo*) ..	77·2	93·6	93·1	94·5	96·7	98·2	98·3	05·6	90·5	87·7	87·7	82·6	54
Matki (*Phaseolus aconitifolius*) ..	90·0	93·8	98·7	91·6	93·3	91·2	90·8	93·7	80·5	71·2	71·2	72·6	63·6
Udid (*Phaseolus mungo* var. *radiatus*) ..	72·2	98·1	97·3	97·7	98·3	97·7	97·2	95·6	93·3	58·1	58·2	42·3	20·7
Deshigram (*Cicer arietinum*) ..	96·6	99·8	98·0	93·2	97·5	98·7	99·0	98·8	96·8	65·7	65·7	9·1	3·8
Hulga kulti (*Dolichos biflorus*) ..	99·0	98·5	98·2	98·1	97·6	93·2	87·0	55·3	10·6	1·1	1·1	0	0
Kabuli gram (*Cicer arietinum*) ..	97·0	99·0	98·7	96·7	97·2	92·3	78·7	42·3	21·0	0	0	0	0
Cotton (*Gossypium neglectum*) ..	58·6	67·3	58·0	55·8	53·3	48·5	27·5	5·7	0	0	0	0	0
Groundnut (Small Japan) (*Arachis hypogea*) ..	92·2	74·5	60·2	28·5	23·8	4·5	0·5	0	0	0	0	0	0
Safflower (*Carthamus tinctorius*) ..	97·3	98·5	96·6	96·6	94·7	91·1	80·1	46·0	0	0	0	0	0
Til (*Sesamum indicum*) ..	85·9	95·8	85·6	79·2	80·5	70·3	42·7	3·1	0	0	0	0	0
Linseed (*Linum utilitissimum*) ..	98·0	97·3	93·0	94·1	93·9	91·1	88·2	64·2	12·8	3	3·5	0	0

It is added that longevity tests on additional crops showed that rice can be stored without much loss of germinating capacity for 4 years, *Capsicum annuam* and *Setaria italica* up to 4 or 5 years and lucerne up to 7 years.

5. *Freedom from Pests and Diseases.*—Seeds should be free from diseases and pests and the defects of bad storage. Badly stored seeds become mouldy and more frequently are much damaged by insect attacks. This can be easily made out from the appearance and the smell. Both grains and pulses are subject to weevil attacks in storage and bulk seed is seldom free. Usually the percentage is considerable and such seed should preferably be rejected but if there is no choice in the matter then a germination test must be made and the seed rate increased according to the percentage of germination.

In the case of seed or planting material of crops like potatoes and sugarcane, there are often characteristic outward marks of serious diseases, which may be transmitted to the crop from the seed. These are 'ring' disease, wart disease and scab in potatoes, and borer pests and red rot in sugarcane. The ring disease in the potato is made out by the black ring-like margin seen in the cut set, and warts and scab easily betray themselves by their characteristic appearance. Similarly in the case of sugarcane a red streak or patch in the cut edge and in the interior when the set is split is a sign of red rot. All such seed material has to be rejected. The same applies to the borer pests also but this is not so serious as the red rot.

There are other seed-borne diseases like the various smuts of the grain crops which cannot be made out by appearance. If the seed supply should be derived from crops (whether the farmer's own or not) which have suffered from such attacks the only course is to treat the seed with fungicides like mercuric chloride, copper sulphate, cerasan, formaldehyde, flowers of sulphur or others which may be recommended for the purpose. Other smut diseases and rust diseases cannot be controlled by seed treatment and their occurrence in the crop must be looked upon only as an act of God; some safety can be secured if seed should be got only from areas which have been inspected previously and found to be disease-free but this is a counsel of perfection and may not be possible to any great extent. In the alternative resort must be had to disease control measures if the disease breaks out and where really efficient methods are available.

Selection of Seed

Much benefit can be derived if farmers bestow some care in the selection of seed in their own fields when the crop is standing. The best plants conforming to the type in view whether it is yield, habit of growth, disease resistance or other characters can be marked down suitably in the field and can be harvested separately and the seed cleaned and preserved carefully. The most general character aimed at will of course be the yield and the plant therefore bearing

the largest and best earheads in the case of grain crops may be selected for seed purposes. A continuous year-to-year selection of this kind will greatly help in maintaining a high level of yield (other factors remaining favourable), if not actually increasing it. This is of course a rough and ready method and does not take note of the various interfering factors which a regular plant breeder will attend to, in evolving a new strain by selection. In respect of the control of certain diseases, selection from disease-free plants for seed or planting material, if practiced regularly, will be an effective way of avoiding the outbreak of disease in the crop. The rather serious disease called "mosaic" in sugarcane has been found to be particularly amenable to this method of control. In fact, both in the case of grain crops and in the case of many other field crops undoubted advantage can be secured even by this simple method of "selection". Whether it is possible to effect great or real improvement or increase in yield by the method of "selection" alone is doubted; on the other hand, it is well known that in many crops like maize, sugar-beets and cotton and in many flowers and fruit crops, very striking improvement in respect of several important characters has been effected. Whatever may be the limitations in highly controlled plant breeding work, it cannot be doubted that under ordinary cultivation there is room for the profitable use of selection (see also Chapter on "Improved Varieties and Crop Production").

Selection has to be carried out not only on the field in the above manner but also in the barn. This latter selection is for the purpose as already explained, of obtaining the heaviest seeds and for eliminating the lighter ones, and for cleaning and thoroughly drying the seeds before storage.

Treatment of Seed Before Sowing

The seeds of certain crops are subjected to some kinds of treatment before sowing, for different purposes, some of which are of a special character while others are ordinary. These purposes comprise: (1) convenience in sowing, (2) the control of disease, (3) protecting against white-ants, (4) hastening or facilitating germination, (5) inducing earliness, (6) increasing the yield, (7) inducing variation in the progeny.

1. *Convenience in Sowing.*—This applies particularly to cotton-seeds. On account of the fluff adhering to the seed, which is very pronounced in the New World cottons and less so in Asiatic cottons, they cling together and cannot be easily sown either through drills or broadcast. In order to get over this difficulty, the seed is so treated that the fluff becomes pasted on to the seed, after which the seeds cannot adhere to each other but roll apart just like the grains or pulses. For this purpose the seeds are rubbed together with a paste made of wet cowdung and earth and then dried; elsewhere a paste made of some kind of starchy flour is used and the seeds rolled

along with the paste in barrels and then used for sowing. The fluff can also be removed altogether by burning or dissolving it off, for which purpose strong sulphuric acid and zinc chloride are used respectively. The seeds are dipped for a short time in these (2 minutes and 10 or 15 minutes respectively), taken out, washed free of the material, thoroughly dried and sown.

The seeds of coriander are prepared by splitting them into two locules of which each seed (fruit) is made up, so that the real seeds fall apart and both economy and evenness of sowing are ensured; otherwise two plants will spring up from each 'seed'. With some crops like sugar-beets, this cannot be avoided, and so later on after the plants come up, they have to be thinned to singles. Coriander seeds are rubbed down lightly under the foot for the purpose, and they split readily into the two halves. In the case of garlic, the compound bulb, which is the form of the produce, has to be pulled apart into the individual ones or "cloves", which is the form in which it is to be sown as seed.

In the case of some seeds the preparation consists in mixing them with earth, ashes or manure before sowing. This applies to very small-sized seeds like ragi, the different millets, gingelli, tobacco, etc. In this way the seeds can be sown evenly and to the required thickness. It is really like diluting the bulk, so as to obtain a larger quantity which can be handled more conveniently.

2. *For Disease Control.*—Treatment is also common for the control of disease. This is especially the case for controlling smut in the grain crops. Hot water, formalin, copper sulphate and many proprietary preparations like 'cerasan', 'phygon', 'spergon', etc., are used for the purpose. Sulphate of copper is the commonest and a grain like jowar is immersed in a 1% solution for 10 to 15 minutes and then taken out, dried lightly and sown. A 'dry' method is to mix the seed with a dust of flowers of sulphur, by rolling the mixture about in a drum and then sowing the sulphur-coated seeds.

3. *For Keeping Off White-Ants and Other Ants.*—For a somewhat similar purpose, seeds are treated with some kind of repellent, so that ants may not carry them away or as in the case of sugarcane sets, white-ants may not damage the sets. Seeds are for this purpose lightly rubbed over, just enough to impart a smell, with kerosine or camphor. This is usual in the case of seeds which are first sown in a nursery for transplantation later on. For sugarcane sets a number of substances are used, none of which however can be said to be quite effective; these are kerosine, asafœtida, stinking aloe, light tar mixture with water, the gum known as 'dekmalli', castor oilcake powder stirred up in water, neem oil or oilcake, etc.

4. *For Quickness of Germination.*—Seeds are treated for quickness or facility in germination, especially those with a hard seedcoat like indigo, lucerne, wild indigo, etc. The treatment consists in abrading their surface to some extent by mixing them with coarse gritty sand and trampling the mixture in a bag or pounding it lightly

in a mortar with a wooden pestle. If this is not done they will take too long to germinate.

Seeds are sometimes soaked in plain water for 24 to 48 hours to induce incipient germination as in the case of rice, or for quickness of germination as in the case of cotton. In the case of American cotton (both D.A. and Cambodia) and of Egyptian and Sea-Island cotton it has been found beneficial to sow the seeds after 12 to 24 hours of soaking in water.

5. *For Better Yields.*—Certain special treatments are claimed to produce increased yield in the treated crop. For example, in the case of sugarcane sets, soaking of the sets in warm water (85° F. to 95° F.) for 24 to 48 hours is reported to give improved germination and greater vigour in the crop, and even better yields if the water contains about 1% of calcium nitrate.

Even for other crops the soaking of seeds in plain water in this way is said to give better yields, which if true is probably due to the better start the seedlings will get. Increased yield is also claimed for the treatment of the seed with a paste of cattle manure and cattle urine (the latter especially), in which the seeds are to be soaked overnight, instead of in plain water as in other cases.

A variation of this method is to soak the seeds and dry them in the shade alternately four or five times, in either plain water or dilute solutions of various salts such as common salt, sodium sulphate, calcium chloride, ammonium sulphate, etc., and then to sow the seed so treated. It is claimed that such seeds germinate better and yield plants which are more hardy and are able to withstand considerable shortage of water and even some salinity in the soil (J. J. Chinoy, *Ind. Farming,* Feb. 1947).

Markedly increased yields are reported to result by the soaking of seeds in soluble phosphates and then sowing them. Wheat is recommended to be soaked in half its weight of a 5% solution of potassium hydrogen phosphate and then to be dried at 22° C. This method is also said to be better than applying phosphates to the soil in the usual way, as it has been found to be 60% more efficient. Similar treatment is also recommended for oats and barley (Experiments by the Imp. Bur. of Soil Sc., Harpenden, England). Similarly, the soaking of seed paddy in a 20% solution of tribasic potassium phosphate is reported to have resulted in an increase of 38·8% and that soaking in a 10% solution to 21%.

6. *For Increased Nitrogen Assimilation by Legumes (Soil Inoculation).*—Another special treatment of seed applies to the leguminous crops, which in some cases are treated with advantage with bacterial cultures, of the root nodule bacteria. There was some vogue at one time for this practice, which has the effect of stimulating the growth of the particular nodules and of the assimilation of atmospheric nitrogen by the crop leading to better growth and higher yields. The procedure was intended to provide against the absence of such bacteria in the soils concerned, which if they had

not grown the particular legume previously are generally devoid of such bacteria and therefore not favourable to the growth of the legume. If other conditions in the soil are favourable, the result of such treatment is satisfactory; but in practice it is only exceptional to find such soils and as moreover the same result, as far as the 'soil inoculation' is concerned, can be obtained by merely scattering some soil from a field where the legume is known to grow well, the need for such seed treatment by 'inoculation' seldom arises.

7. *For Inducing Earliness—"Vernalisation".*—A very special kind of seed treatment relates to what is called 'Vernalisation'. Seeds so treated give rise to crops whose period of maturity becomes shorter than the normal period, which is taken when the seeds are sown without this treatment. The reduction may amount to many days or even a few weeks. The result is that a crop or variety which on account of the length of the period of growth cannot be grown in a climate with a very short growing season (like the cold regions of the far northern latitudes) can be successfully grown with the help of this special seed treatment. Even under ordinary circumstances, the advantages of a shortening of the growth period of a crop are obvious and important. In addition to the reduction of the growth period, an increase in the yield is also sometimes claimed. The method broadly is as follows:—The seed to be treated is soaked in water and incipient germination is induced, that is to say, a kind of awakening of the dormant embryo and the commencement of the changes in the endosperm favouring germination. After this stage the seeds are put in cold storage, that is, further progress of germination is halted, and held at a temperature which will not kill or reduce the germinating capacity. Other precautions are taken to prevent mould and damage therefrom. The seed is held in cold storage in this way for varying periods—which is a matter for experiment and which may in cases last through the whole winter—and then taken out and sown. There are important variations in the treatment, peculiar to different crops and climates, in the matter of the temperature at germination and thereafter, period of storage, etc., which however are still not definitely known. The principle on which the method is based is that the plant spends part of its vegetative period or phase in the sprouted seed, the seed so treated being regarded as the plant itself. The period from sowing to flowering is therefore reduced very materially, so much so that in Soviet Russia it has made it possible to grow wheat in the higher latitudes also where the cultivation was impossible in the ordinary way, and thus to increase her wheat-growing area enormously. In other countries and with other crops the different aspects, both technique and results, as regards earliness and yield are still matters of experiment.

In India 'vernalisation' has been tried in the case of a few crops in an experimental way but the results appear inconclusive and even contradictory. Rice (of different varieties), jute, cotton, mustard, wheat and jowar have all been tried. There has been either

no shortening of the period or the shortening has been too small to be of practical value. On the positive side, results obtained at Almora by Boshi Sen on mustard, those at Powerkhera (C.P.) on wheat, at Lyallpur on jowar, may be mentioned; the last is about the most encouraging. Jowar was vernalised in darkness at a temperature of 16° C. and the crop raised therefrom induced earliness by 12 days and gave a higher yield. Many factors like variety, soil and climate seem to influence the response to the treatment and as far as India is concerned the matter is only in the experimental stage.

It is interesting to note that recent experiments show that in the case of legumes such as peas, the vernalisation of the seed greatly stimulates and increases the formation of root nodules and leads further to increased yield of the crop, even though the period of earliness induced by the process may be very small and almost negligible.

8. *Seed Treatment for Inducing Variation.*—Another very special purpose for which seeds are treated is for breaking the type and inducing variations or mutations in the progeny. This is part of the plant breeder's technique and consists in subjecting the seeds to the action of X-rays. As the result of this kind of bombardment, profound and fundamental changes in the genetic make-up of the seeds are produced and when the treated seeds are sown, they give rise to progeny of many different types from the parent, comprising a large number of new varieties, from which superior types or varieties can be selected. In the case of sugarcane some good varieties have been originated by this method. On the other hand, seeds of tobacco, mustard and bajri treated in the same manner gave rise to a weak progeny, with general loss in growth. There is indeed as much chance of getting poor varieties as of good varieties.

In more or less the same way both seeds and planting material like vegetative parts such as cut stems, and leaves, are treated with the chemical 'Colchicine' which also has the effect of altering the genetic composition. All these are however only laboratory treatments and the methods are used for special scientific work of plant breeding and are obviously outside the scope of ordinary farming practices.

Treatment is also sometimes given to the vegetative parts in order to induce rooting quickly for purposes of vegetative propagation,principally of cuttings. The substances used for the purpose are ordinary cattle urine and various chemicals belonging to the indoleacetic acid group, and others.

Proprietary preparations of root-promoting hormones under the names Seradix A, Seradix B and so on, are now much used in vegetative propagation, and notable work is being done on these lines in the production of rooted cuttings of coffee on the Coffee Experiment Station in Balehonnur, Mysore. It is reported that nearly 49% rooting was obtained with these preparations, as against 22% in controls, and that *Glyricidia maculata* cuttings rooted freely when

the cut ends were treated with ·005% solution of indole-3-acetic acid or with ·1% solution of Seradix A.

It is also reported that in potatoes the period of dormancy can be reduced by some months if the tubers intended for planting are dipped in a 1% solution of "ethylene chlorhydrin" taken out, kept in a closed vessel for 24 hours and then planted.

The Sowing of Seeds

The seedbed having been prepared by the various tillage operations described, and the seeds also treated (where necessary) and ready, the sowing of the seeds is taken up. Some important points have however to be borne in mind in this connection.

1. Firstly comes the moisture content of the soil. A proper degree of moisture is necessary for germination and this important condition should be satisfied before sowing can begin. It is only in very exceptional circumstances that seed is sown, in the seedbed in anticipation of rain on the strength of the proverb 'Better to have the seed in the soil than in the pot'. At the same time the soil should not be wet, as the seed-drill tubes will become choked with wet mud and many blanks will be left or the soil made difficult for being stirred with harrows after the sowing has been done whether by drill or broadcast.

2. *Depth of Sowing.*—The depth at which the seeds should lodge in the soil when sown and the evenness or proper spacing of the seeds in the soil are also points to be attended to. Seeds should lodge at a depth where the necessary moisture is to be found and as the top soil is, and indeed has to be, somewhat dry in order to avoid choking of the drill tubes, seeds have to fall and lodged at some little depth below the surface. At the same time the depth should not be too great for the young seedling to send up its shoot to the air and light above ground, sufficiently quickly. At such depths although seeds may sprout readily on account of the moisture, the young seedling may spend itself before it pushes up its plumule, into the light and enable it to function and assimilate before the endosperm is exhausted. If this above-ground appearance is much delayed, the seedlings are weakened and may even rot away. The correct depth may vary with the kind of seed and generally corresponds to its size; the smaller the seed the more shallow it has to be sown than the larger-sized seeds. The theoretical maximum depth which may be permissible is not of much importance in practice as seeds sown in drills or plough furrows cannot lodge more than 3" in depth. Within this limit, the larger seeds like cotton, castor, jowar and the larger pulses can be sown deeper than the small seeds like gingelli, ragi, mustard, etc.

As a general rule a depth of 1" is correct for the smaller seeds and 2" to 3" for jowar and seeds of that size or larger.

In a very interesting set of experiments on the correct depth of sowing for several agricultural crops in which seeds were sown at

different depths of 1″, 1½″, 2″, 2½″, 3″, 3½″, 4″, 4½″ and 5″ it was found that the small-sized seeds like til, mustard (sarson), bajri, *Panicum colonum* and Sudan grass, germinated best up to a depth of 1″, after which the germination fell off, either ceasing altogether or becoming negligible at 4″ or 4½″. The seeds of the grain crops with larger seeds like wheat, barley, oats and juar came up best up to 2½″ and then fell off, but even at a depth of 5″ the percentage was about 65. The large-seeded grain crop, maize, came up best up to 3″ and even at 5″ germination was 76%. Likewise the seeds of the pulses or legumes, cowpeas, mung (or greengram), mash (or blackgram), moth (*Phaseolus aconitifolius*), sannhemp, guara, came up best at 2″ to 3″ but even at 5″ gave a germination of about 75%. The case of cotton is interesting, in that the small-seeded local variety of cotton came up best at 1½″ and became negligible from 4″; the large-seeded American cotton required a depth of 2″ and became negligible only about 5″. The pulse crop gram (*Cicer arietinum*) was found to be particularly unaffected by depth; the best germination was at 3″ depth and though like the others it fell off thereafter, the drop was very little, as even at 5″ the percentage was as high as 88 (Lab Singh and Nek Alam, *Ind. Jl. Agl. Res.*, Vol. VI, page 784).

3. *Evenness of Sowing.*—Evenness in sowing is important not only to ensure to the seedlings ample room for development but also to avoid the need later on for considerable work in thinning, transplanting in bare patches or too widely sown spaces, etc., and to economise seed. When seeds are sown whether in rows or broadcast, considerable skill is required in ensuring such evenness. When sown in rows, evenness is assured at least in one direction, *i.e.*, the distance between the rows is uniform and only the space between the seeds in the rows has to be adjusted in the sowing; this is a matter depending upon the care and skill of the person sowing the seeds. In broadcasting or scattering seed by hand, evenness of sowing is difficult to secure and there is also risk of leaving considerable spaces unsown. To avoid this risk, the field should be divided into regular narrow strips of about 6′ to 8′ by means of plough furrows, which will thereafter serve as a guide to the sower. Broadcasting is done in strip after strip and the risk of unsown spaces is largely reduced if not altogether avoided. Mistakes can be and are remedied later on after the seedlings come up and the bare spaces become noticeable, but this means more work and if moisture conditions are not suitable, may not be possible at all.

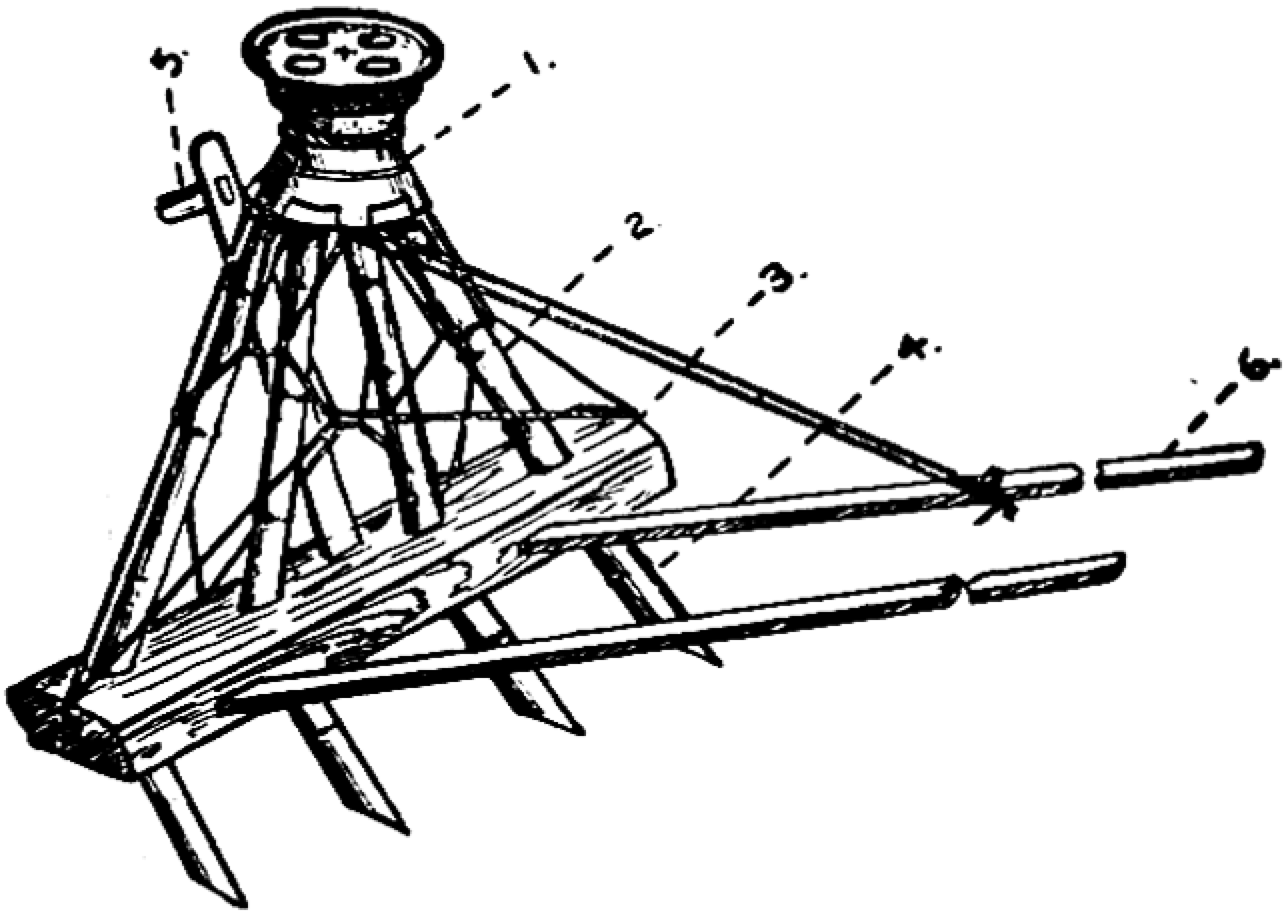
Methods of Sowing

Broadcast Sowing.—Sowing is carried out either by broadcasting or in rows through drills or in plough furrows. Broadcasting is usually a purely manual operation and is subject to the drawbacks of uneven sowing, etc., but it can be carried out much quicker than drill sowing. Broadcasting can be carried out more evenly and

quickly by means of broadcasting machines, of which there is more than one type. Seed is carried in a narrow seed box, mounted on a carrier somewhat like a wheel-barrow, and the machine is so geared that as it moves along, seeds drop through a narrow opening in the box and are whirled about as they fall on a rotating disc which is set in motion by the gearing. For small-sized grains like ragi, bajra and other millets, the machine should be found useful, provided adjustments are made for reducing the seed rate very considerably, as it is found that these and other drills made for European and American conditions sow much too large a quantity per acre.

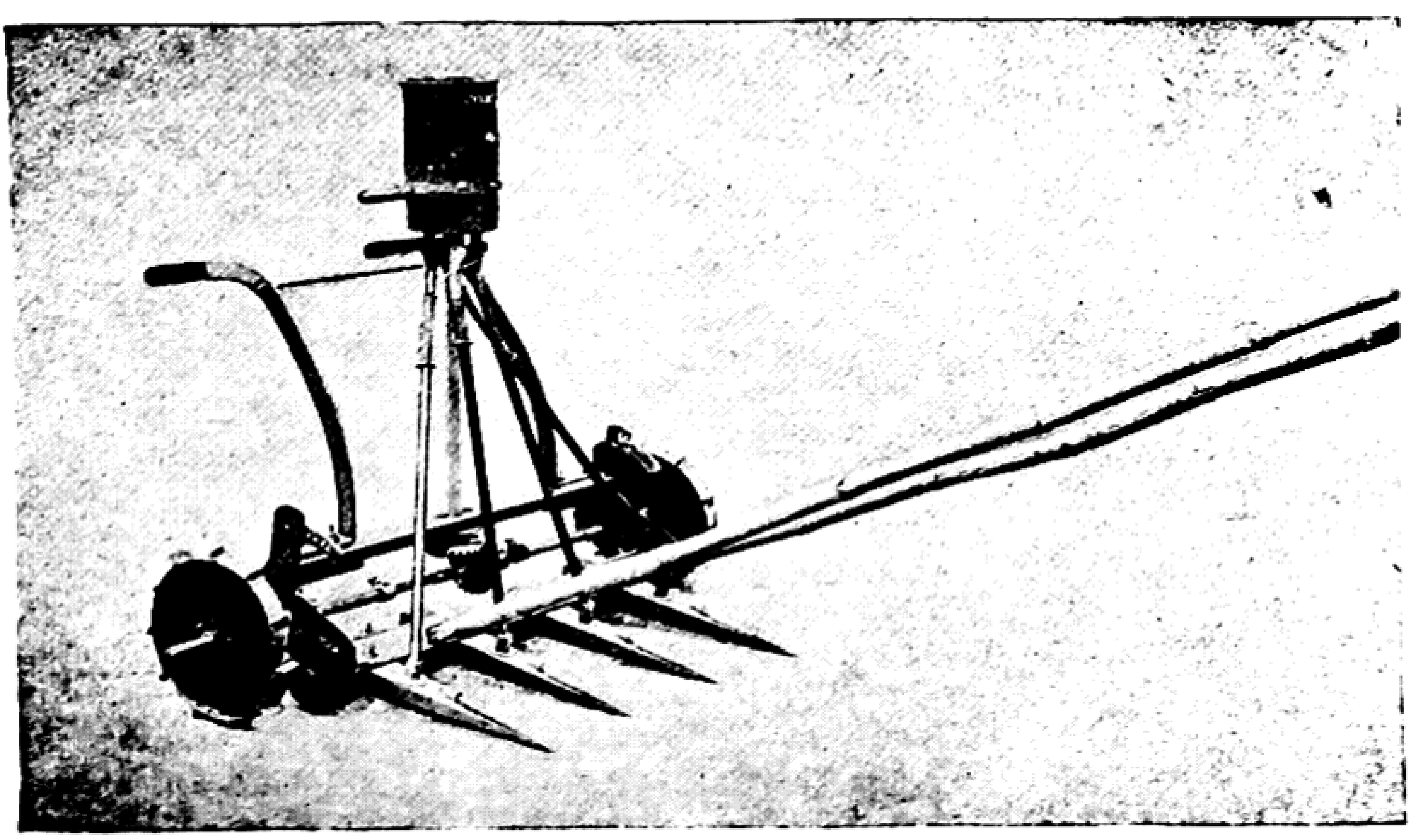
Drill Sowing.—In many parts of India, drill sowing is common and all these drills are very light and well adapted for bullock draft. They are all made in one general pattern and consist of a seed bowl which communicates with one or more seed tubes, the latter serving to pass the seeds through from the bowl into the furrow in the field. The single tube drill is worked by attaching it behind a plough, which opens the furrow into which the seed is dropped through the drill tube. Other types have two, three, four, six or even twelve tubes (the last being peculiar to Mysore for sowing ragi) which are connected to and communicate with the seed bowl at the top and with furrow-opening shallow cultivator teeth below, the whole tied into a rigid arrangement for being drawn by a pair of bullocks. The tines or teeth are spaced at different widths for different crops varying from 6" to 2' and even 3'. There are slight differences in detail; in some the tines themselves pass the seed into the soil, and are therefore liable to get choked, and in others the tines merely open furrows and the seeds drop behind into the furrow; some have a line-marker tine in addition but others are without. In all of them the seed is fed into the bowl by hand, and carelessness or neglect may lead to unevenness of sowing. Improved drills for making the feeding automatic have been made and worked with a certain amount of success but the indigenous types cannot be displaced as they are very simple in construction and cheap and despite drawbacks, are fairly efficient.

Drills of the European and American pattern, although they are rather complicated and very costly in comparison with the cheap and simple local Indian models, deserve consideration at least on the larger farms, whether individual or co-operative. They are as a matter of fact already in use on some of the farms in the Panjab. These drills have the great advantage of automatic mechanical feeding; they sow without leaving any gaps and at a regular and uniform depth. They are adjustable to different rates of sowing. The seeds are carried in a long rectangular box, which has apertures communicating with the seed tubes, which pass down the seed as the machine moves along. The seeds are picked up from the box either by tiny cups mounted on a sprocket chain, or by little depressions on the periphery of small rotating wheels and delivered into the seed tubes. This feeding arrangement is geared to the wheels of



A four-row seed drill, of the local Mysore pattern. 1. seed bowl, 2. seed tubes, 3. wooden frame, 4. furrow openers which also sow the seeds, 5. handle, 6. bars for carrying the yoke.

From the Author's "An Elementary Text-Book of Agriculture" in Kannada



The Mysore type of seed drill, improved and adapted to automatic sowing, designed by the Mysore Department of Agriculture.

Mys. Agr. Dept.

the machine and is set in motion as the machine moves. Machines are of different sizes, sowing up to 12 rows at a time. For small-sized seeds like ragi they have been found unsuitable but for the somewhat larger ones like jowar, wheat or cotton they should be found suitable. For bullock draft moreover the machines will have to be only of the smaller sizes such as those which will sow, say, 4 rows.

Dibbling.—Larger seeds like beans, castor, etc., are dibbled in by hand; usually plough furrows are drawn at distances of 3′ both along the length and across the field and at the intersections of these furrows a few seeds are dibbled in by hand. This of course is the slowest among the methods but there is no room for any mistake or unevenness, and the later operations are also fewer.

SEED RATE AND SPACING

The quantity of seed to be sown per acre (or the seed rate) should, strictly speaking, be such as to give the number of plants necessary to yield a maximum crop. Crops of course differ from each other in this respect, on account of the particular habit of growth of each crop, that is to say, upon the amount of space required for normal growth. Crops with a branching habit or with a large tillering habit will require more space than others and therefore a smaller number will be sufficient for an acre. Knowing the optimum space required, the number of plants can be easily reckoned, and theoretically the quantity of seed which will give this number ought to suffice. The nearest approach to this condition will be reached in the case of seeds which are dibbled by hand, or dropped at regular intervals, such as in the case of castor seeds. Where seedlings are raised in a nursery and then transplanted, an even better approach is secured (although this is not a case of sowing). Where the distance between plant and plant in the rows and between the rows themselves is known, then the number which goes to the acre is easy to calculate. This figure is given by dividing 4,840 by the product (in sq. yds.) obtained by multiplying the above two distances. Thus if the distance is 3′ each way then the number is $= 4{,}840 \div 1$ (*i.e.,* 1 yd. $\times$ 1 yd.) or 4,840 plants; if it is, say, 3′ between rows and 1′ in the row, then the number of plants will be $4{,}840 \div 1/3$ (1 yd. $\times$ 1/3 yd.) or 14,520.

The quantity of seed sown per acre in practice is vastly more than the quantity which will give this number of plants. The reason is mainly one of providing against risks due to non-sprouting on account of various causes, and to the loss which is inevitable in the process of harrowing and interculturing, which will follow later on. Added to this is the practical difficulty of sowing very small quantities so as to cover the large area uniformly. Though sometimes got over partially by mixing the seeds with earth or manure as already stated, this difficulty is a real one and has to be reckoned with.

Balanced against these considerations especially the important one of insufficient or patchy germination, the question of reducing the seed rate very materially becomes one of minor importance. In practice therefore much more seed is sown than is necessary and the correct spacing is given later on by the removal of unwanted plants in the interculturing.

It has been repeatedly found that as far as yield is concerned there is no advantage in increasing the seed rate, in the belief that the yield is generally a definite multiple of the seed sown. For instance, wheat sown at the rates of 10, 30 and 40 seers per acre was found in experiments in Panjab to yield at the rates of only 17 md., 16 md. and 16½ md. respectively in one year and at 21 md., 18 md. and 17 md. respectively in the following year (quoted by J. C. Luthra), showing that as far as yield is concerned the excess over 10 seers of seed, whether 20 seers or 30 seers, has been a waste. The total so wasted in the shape of seed by farmers should be a stupendous quantity and the question of avoiding or preventing the losses as an insurance against which too high a seed rate is adopted has to be studied carefully and steps taken to improve sowing methods.

The correct spacing which will lead to the best yield is a matter of experiment in each case even within the two groups, *viz.,* the non-branching and the branching. Even in the case of a grain crop like jowar or maize which normally neither tiller nor branch, it will be necessary to afford ample space between plant and plant for the development of the stem and leaves and later of the earhead or cob of grain. In the case of those like ragi, rice or bajra which tiller much and where therefore increased yield may be expected by inducing abundant tillering by very wide spacing, considerations such as concentrating the energy of the plant into a few good tillers and earheads, and the need for uniform and simultaneous ripening, will impose a limit on the space that may be advantageously allowed. In the case of branching crops, like cotton, castor, etc., the widest spacing will be twice the length of the average branch, so that the rows more or less close in when the plants are well grown, but even this may be found sometimes undesirable. On rich soils planting or sowing may be wider than in poor soils. Spacing will also depend in the case of branching crops on the manner of branching, as in the case of the American and local cottons, in which the latter are sown much closer than the former. In addition, spacing may differ according to the purpose for which the crop is being grown; jowar required for fodder has to be sown very thick so as to yield thin succulent fodder which will be eaten without wastage, sannhemp required for fibre is also sown very thick in order to prevent branching, and so on. It is an interesting fact that a large number of experiments on many farms in India relate to the spacing best suited to the different crops.

Compacting the Surface After Sowing

Sowing is sometimes followed (as indeed part of the operation) by a certain amount of firming up or compacting of the surface. This has the effect of bringing up the moisture from below close to the seeds and helping germination thereby. This compacting is done by dragging a log roller or board over the field or by the curious practice of driving a herd of sheep over the field. Even this compacting is followed by a very light harrowing, in order to prevent the loss of moisture and to retain it near the seeds after it has risen by capillary force as the result of the compacting (see also chapter on "Dry Farming").

Nursery Sowing and Transplantation

Nursery Sowing.—In nursery sowing, seeds are sown only for raising seedlings, that is, plants which will remain in the nursery only for a few weeks making only very little growth, and therefore need very little space; seeds are sown very thick and the seedlings come up close to each other, filling almost the whole surface of the nursery. As the seedlings will have to be transplanted in their permanent places at greatly wider intervals than they occupy in the nursery, the nursery plots will provide seedlings for areas many times larger, which may go up ten times their own extent. Nevertheless it is a great advantage that even in nurseries plants should get more space and that the sowing should not be unduly thick. More space leads to stronger and stockier seedlings than those raised in a crowded nursery and these stronger seedlings will stand the transplanting better than thin lanky ones. In fact in horticultural practice seeds are often dibbled at regular distances of an inch or so even in the nursery or seed pan.

Seedlings are left in the nursery only until they are well established and strong enough to withstand the shock of transplanting. They are pulled out for transplanting before their nodes begin to form or branching begins. For different crops the stage varies slightly, but seldom exceeds six weeks; there is found to be a relation between the age of the seedling for transplanting and the period taken by the crop for maturing. For example, an early maturing rice will require younger seedlings than the late maturing ones; in rice, about one week is reckoned in the age of the seedling for every month of the period for maturity.

Transplantation.—The transplanting may be only in one stage or in more than one, sometimes as many as three or four being not uncommon in the case of orchard crops or forest trees. In ordinary field crops a single transplantation is the general practice; occasionally rice is transplanted twice. Where there is risk of damage or loss of vigour due to heavy rains or floods, the double transplantation may be an advantage on account of the extra strength of the seedlings.

In the process of removal from the nursery for transplanting, damage to the young roots of the seedlings has to be avoided and for this purpose nurseries are watered heavily and the soil well softened immediately before the seedlings are pulled out and for the same reason the transplanting is done in soil well prepared and watered beforehand or to be watered immediately after. In plantation crops seedlings may be lifted with the ball of earth round the roots so that the latter are intact.

In the setting out of such transplanted plants whether of trees or plantation crops, at whatever distance it may be decided upon, two methods are possible either of which may be adopted. One is the square system and the other the 'triangular' (also called the 'quincunx') system. The latter gives some 15% more plants in the same area, though the distance is the same between plant to plant as in the square system. Where a much larger number of plants has to be put in, a combination of the square and the triangular system is adopted; in this system an extra plant is put in at the intersection of the diagonals of the squares. This will give quite 75% more plants than in the square system, which makes the area very crowded. Very often this planting of an extra tree is carried out many years afterwards (some 15 or 20 years) in arecanut gardens after the first trees were put in; or in the beginning itself when the centre plants are intended to be removed after some years and only the corner plants left as permanent trees with ample room. All these however pertain to the planting of orchards and plantation crops, but the principle that each tree should be given the necessary room without any detriment to its neighbour is kept in view. The most economical grouping which gives the maximum number any area may carry may be seen in the arecanut gardens of the Mysore malnad, where the system secures this maximum by planting of different age groups, by which though the ground is fully covered by the tree tops, the canopies do not touch each other and interlace.

CHAPTER XIV

ROTATION OF CROPS

IT is an important principle in practical agriculture that the same crop should not be grown in a field successively every season but that it should be grown only once in the course of two or more crop seasons in rotation with other crops, which will occupy the field in these seasons. A crop like cotton, for instance, is succeeded by jowar in the next season and may be followed by cotton again in the next season; a crop of ragi may be followed by groundnuts, which may be followed by tobacco, to be succeeded by ragi in the next season. The first is an instance of a two-year rotation in which cotton or jowar is grown only once in two years and the second is an instance of a three years' rotation, in which any one of the crops mentioned is grown only once in three years. In the same way rotations may comprise four or five, even six seasons. Rotations are as a rule adopted in the case of most crops though there are exceptions to which reference will be made later on.

The reasons underlying the practice are the following:

1. Different crops have different root systems both in depth and in lateral development some being very deep-rooted, others shallow-rooted, some spreading much in all directions and others with roots crowding close below the base of the plants. This difference in the habit of the root system leads to the absorption of plant foods from different depths or zones and the successive growing of the same crop year after year on the same field will lead to the impoverishment of particular depths, whereas the growing of crops with different root systems in alternate years will lead to a more even utilisation of the plant food resources in the soil. The growing of the same crop without rotation will for the same reason eventually make the soil unsuitable for the crop. The alternating of a shallow with a deep-rooted crop may be regarded as a method of recuperation for the soil depths or zones concerned. This fact is utilised in practice in the system of mixed cropping also, where deep-rooted crops like cotton, tuver, avare, etc., are grown in association with shallow-rooted grain crops like jowar, ragi or Italian millet.

2. The plant foods are husbanded better in a rotation, because the predominant plant food requirements of different crops are different, some taking up more of one kind of plant food than another. A process of one-sided depletion may therefore take place, unless a change of crops or rotation is practised. It will be seen from the following how greatly crops differ in the quantities of plant foods removed by them from the soil:—

Removed per acre in lb.

	N	P_2O_5	K_2O	CaO
Sugarcane ..	56	68	190	55 (25 ton crop)
Wheat ..	48	21	29	9
Tobacco ..	100	16	150	
Potatoes ..	67	24	77	26

3. Pests and diseases peculiar to any one crop tend to be perpetuated, leading to serious damage and crop reduction, when only the same crop is grown without a rotation. In fact in the case of many crop diseases and pests, the only remedy possible or practicable is a rotation of crops, *i.e.,* to stop growing the particular crop for two or more seasons in the field concerned. Practically every crop will furnish illustrations of this fact.

4. In the same manner some particular types of weeds, among which some are of a parasitic nature, are favoured by particular crops or kinds of crops and the only practicable way in which these weeds can be eradicated is by a system of crop rotation.

5. In regard to irrigated crops those requiring heavy irrigation and expenditure of labour are followed by crops requiring only light irrigations or which can be raised with the rainfall alone. In this way crops can be raised with greater economy, and seasons with a plentiful water supply and those with scanty supply can both be used to advantage.

Such alternation or frequent interposition of a crop requiring less water also prevents the deterioration of the physical condition of the soil which may result from the repeated flooding required for one kind of crop alone. The same applies to the health of the population or sanitary conditions of the tract consequent on such repeated flooded cultivation, in the interest of which a rotation with dry crops or semi-dry crops is necessary.

6. Advantage is likewise taken for raising short season crops at a time when a main or long season crop cannot be raised, with certainty. A number of catch crops, short season vegetable crops, etc., are raised in this manner.

7. Some crops are directly beneficial to the succeeding crops, in more than one way. The legumes, for example, belong to this class, by virtue of their property of assimilating nitrogen from the air and enriching the soil with their root system, which form useful plant residues available for the succeeding grain or other crop.

8. Other crops benefit these which follow them, because, like groundnuts, potatoes or onions, etc., the soil has to be dug for harvesting them and this digging benefits the succeeding crop, as it kills many weeds, destroys insect pests, helps to weather the soil and may be looked upon as a recuperative and cleaning process.

9. Soils on which the same crop is grown without any rotation often becomes 'sick' for that particular crop, which cannot therefore be satisfactorily grown on such soils. The 'sickness' is no

doubt due to the cumulative result of all the factors mentioned above, but in addition, it is held, that crop roots exude into the soil secretions which prove poisonous to the crop if they accumulate. That plant roots do secrete something injurious to certain kinds of vegetation has to be accepted, because some crops cannot be grown near to or in association with certain others. Fruit trees are injured by grass, and cotton on the black cotton soils is greatly affected by the grass *hariali* or *dub* (*Cynodon dactylon*). Though definite poisons have not been identified or isolated still that plants secrete some material poisonous to themselves or to their neighbours, when they accumulate or are not neutralised by other factors, cannot be ruled out (see also under "Mixed Cropping").

10. Above all, that rotation in practice (on account presumably of the operation of all these factors) is exceedingly beneficial is shown by the following classical experiment in the Rothamsted Station :—

Yield of Wheat per acre in Bushels (not Manured)

Grown continuously	Wheat alternating with fallow	In four course rotation	Experiment over
11·3	14	24	76 years

A better proof that the practice of rotation is based upon sound principles cannot be adduced.

11. Many important practical and economic considerations require that a variety of crops should be grown on ordinary farms; these are, for instance, for meeting the domestic needs of the farmer and his live-stock; reducing the risk of losses due to market fluctuations in price, pests and diseases, unfavourable weather conditions, etc. Furnishing work throughout the year for the men, machines and bullocks on the farm; for keeping down costs by the growing of expensive crops along with others which do not involve much expenditure and so on. All this variety of crops can, for the reasons explained above, be grown more advantageously, in a system of rotation than in the same field year after year.

How the Rotation Should be Decided

The principles on which the different crops should be selected and their sequence in the rotation decided, follow more or less from the reasons for rotation explained above. The crops usually consist of food crops, fodder crops and money crops and the selection is governed further by the tract, the season, soil and in the case of irrigated crops on the extent of the water supply. Very intensive cultivation requiring the use of heavy manuring for all the crops is exceptional and in ordinary farming the crops comprise those which require heavy manuring and others which require only moderate or little manuring, so that the farmer will be able to grow the different crops required by him without having to purchase manures for every crop. A heavily manured garden crop may thus be followed by

some cheap grain or fodder crop which makes use of the residual effect of the heavy manuring. In the same way some minor or catch crops like pulses may be grown in order to utilise the moisture left over from a crop of rice and the crop raised to maturity or simply used as green fodder.

The crops being decided upon, the rotation will comprise (1) a shallow-rooted grain, such as may suit the tract or be needed by the farmer; (2) a deep-rooted crop usually a money crop; and (3) a restorative crop. This will provide food (grain) and fodder (straw), cash (from a saleable commercial crop like cotton) and a soil ameliorant or enrichment as in the case of a legume.

An example of a rotation which will satisfy these conditions is the following, *viz.,* on the black cotton soil, 1st year jowar, 2nd year cotton, 3rd year groundnuts in the course of three years, only one crop being grown each year. It may be possible (and in many places usual) to grow two crops in the same year, one in the early monsoon and one in the late monsoon, in which case an additional restorative and fodder crop like horsegram may follow the jowar crop in the same year. In the above rotation the groundnut crop forms the cleaning crop as well.

The Norfolk Four-Course Rotation

In England where agriculture comprises animal husbandry, as well to a very large extent, a famous rotation is the Norfolk Four-Course rotation which illustrates the principles of rotation admirably. This rotation is as follows: 1st year, grain (oats, barley) with clover sown as a mixture which can be fed after the grain crop is harvested and removed; 2nd year, clover continued from the previous year's sowing and furnishing both mown hay and grazing; 3rd year, grain for human food, *viz.,* wheat; 4th year, roots, *i.e.,* swedes, mangolds, turnips, etc., solely for cattle feed. In this rotation, the wheat is the main food crop; in the barley and clover crops, part of the barley is for brewing, and the bulk of the barley and the whole of the clover are cattle feed; the clover later on is entirely for cattle feed; the root crops are also solely for cattle feed. It will be seen that only one-fourth of the total crops on the farm is for human food, while three-fourths is cattle feed (if we exclude the small portion used for brewing into beer), a fact which brings out the great importance of animal husbandry in that country, and accounts for its status as a meat-eating and dairying country. In the above rotation the root crops have to be sown only after thorough cleaning up, by repeated ploughing and weedings and it is also thoroughly to be hoed between the rows after it is sown so that it is the great cleaning crop in that rotation, and comes in appropriately after three years of grain and clover growing during which weed growth reaches its peak.

Special Conditions in India

In India where two sharply divided classes of cropping exist, *viz.,* the ordinary dry land or rain-fed cultivation and irrigated or wet

cultivation and where furthermore crops can be grown in practically any part of the year (provided of course there is irrigation available) rotations are very varied and comprise a large number of crops depending upon these conditions and the individual wants or fancies. Rotations are also sharply conditioned by the two different types of red soil and black cotton soils. Whatever crops may be chosen and whatever rotation is decided upon therein, the general principles explained above will have to be followed.

In irrigated cultivation moreover a further variation may be introduced according as water is available throughout the year or only in a particular season. In the former case crops occupying the land for almost a whole year like sugarcane or turmeric among annual crops and plantains, or betel wine among crops of still longer duration may come into the rotation, to be followed by crops of shorter duration.

In certain cases as in the cultivation of rice, the nature of the surface of the country such as lowlying flats or terraced fields on slopes and the general custom of neighbouring land-holders may make it impossible to grow any crop other than rice year after year. This is indeed peculiar in rice cultivation, that it is grown in most rice tracts in the same field year after year without any rotation, except in tracts where water may be available throughout the year when rotations are possible and are practised. Perhaps, to some extent, the evil of continuous cropping is mitigated by growing different varieties of rice, or growing it partly by puddle cultivation, and partly by both dry and puddle cultivation, or by the system of fallows or an occasional catch crop in the place of the fallow.

FALLOWS IN ROTATION

This brings us to the question of the need for and the usefulness of a fallow year or season to be interposed between two crops in a rotation. A fallow year or season is one in which the field is not cultivated with any crop but left bare, during which the soil may be said to rest. The field during the fallow may be left quite undisturbed or left in a ploughed condition. A fallow year is almost universal among market gardeners, whose cultivation is very intensive and two or three or even four crops are grown in the same field (of course all short duration ones) in the same year, which no doubt exhaust the soil in spite of the heavy manuring. On a field scale this is not much in vogue in this country though in Great Britain it is a common practice. Of course there is the prolonged hot weather between two crop seasons, when the field has to rest but this cannot be helped, in the case of rain-fed cultivation. Even in the case of irrigated rice cultivation where rice is grown only in the monsoon season with canal irrigation, the land lies idle for the remaining 5 or 6 months of the year but this is also an enforced virtue. In any case it is possible to regard them as a fallow.

Fallow and Nitrification in the Soil.—It is a somewhat noteworthy fact that on land with a crop growing on it, the formation of nitrates in the soil is less than on uncropped land, even making allowance for what the crop may be taking up. Whether the fallow is based upon the fact that nitrification is better and nitrates accumulate cannot be said, though it looks probable. As against this circumstance should be put down the fact that the nitrates can be lost in the rains, except when a crop is sown and growth started before the rains begin, as may be possible under irrigation.

Benefit of Fallow in Rice Cultivation.—Reference may be made to the increase in the yield of rice when the crop is preceded by a fallow, as against the growing of different crops during that season instead of leaving the field fallow. The trials were conducted on the Experiment Station, Nagina, U.P., and the results are as below:

Yield of Paddy (Grain) lb. per acre

Treatment	Average of four years	Per cent.	Total profit or loss RS.	A.	P.
Paddy after fallow ..	1708·5	100	32	15	1
,, ,, gram ..	1421·0	83	30	2	0
,, ,, linseed ..	1276·0	75	2	7	8
,, ,, wheat ..	1147·8	67	1	15	0

It will be seen that both from actual yield of paddy and from a financial point of view (actual net money return) the practice has been very advantageous.

Fallow in Dry Farming.—In what is called "Dry Farming" also both in the U.S.A. and in Canada the interposition of a year of fallow (but kept ploughed and free from weeds) between two crop years has been found to be very useful. Experiments in India also (Panjab Dry Farming Station, Rohtak) show that better yields have been secured by growing two crops in three years as against a crop every year. On other Indian Dry Farming Stations also experiments demonstrate the benefit of a fallow year in increasing the yield of crop in the succeeding year, almost invariably. These fallows are of course ploughed fallows. The mentality of the farmer is however not always favourable to a fallow year, as he is generally willing to take the risk and face the uncertainty rather than definitely forego the chance of success, if the rainfall should be satisfactory.

We shall close this chapter with a list of a number of rotations which are practised and usual in many parts of India, which may be taken as illustrations. In some provinces notably Madras and Bombay, the rotations are very varied and numerous due to the different kinds of cultivation like dry, wet and garden (well), the different soils like red soils and the black cotton soils, facilities for water and regional peculiarities. The list therefore comprises only a small number among those practised in such provinces.

N.W.F. Province—

1. Maize—wheat—maize.
2. Rice—shaftal—maize.
3. Wheat—fallow—wheat.
4. Gram—bajra—gram.
5. Shaftal—sugarcane (three ratoons)—wheat.
6. Peas—fallow—peas.

Panjab Province—

(*a*) *Irrigated Crops*:

1. Rice—wheat—rice.
2. Wheat—maize—senji—sugarcane.
3. Wheat—green gram and gingelly—fallow.
4. Wheat—toria—cotton.
5. Tobacco—maize—potatoes.

(*b*) *Rain-fed Crops*:

1. Cotton—fallow—cotton.
2. Wheat—maize.
3. Cotton—jowar and matki—cotton.
4. Bajri—cotton—wheat.
5. Rice—gram.

Bihar Province—

(*a*) *Rice Land*:

1. Rice in kharif followed in rabi by fallow or gram, wheat, moong, linseed or kesari.
   2nd year rice (transplanted) followed by fallow or gram, wheat, moong, linseed or kesari.

(*b*) *Rain-fed Crops*:

	Kharif	Rabi
1.	Ragi, udid and rahar	Rahar or fallow
	Rice	Fallow
	Udid	Fallow
	Gundali (small millets)	Fallow
2.	Rice	Sugarcane
	Sugarcane	Sugarcane
3.	Maize (or mixture of millets)	Sugarcane
	Sugarcane	Sugarcane
	Maize or fallow	Wheat
	Maize, Rahar and Cotton mixed	Rahar and cotton
4.	Maize or ragi	Wheat or barley, or barley, gram and peas, or gram with mustard and linseed
	2nd year fallow or pulse crop	Wheat alone or wheat and mustard or linseed

3rd year fallow	Chillies or tobacco or potatoes
4th year maize	Wheat or barley, pure or mixed, with mustard and linseed

Central Provinces—

1. Cotton—jowar—groundnut.
2. Cotton—wheat—cotton—jowar.
3. Bajri—groundnut or tuver—cotton.
4. Sugarcane—chillies—rice.
5. Gram—wheat—linseed.
6. Rice—rice or linseed.

Bombay Province—

1. Cotton—jowar.
2. Maize (in kharif) and rabi, wheat and gram—groundnuts.
3. Cotton, jowar or bajri—groundnuts.
4. Rice—rice or occasionally val, tur or gram.
5. Cotton—groundnut—wheat or gram.
6. Sugarcane—ratoon—cotton in kharif and gram in rabi.
7. Rice—spelt wheat or gram.
8. Canal irrigation :
   Maize and sannhemp in kharif—sugarcane.
   Maize and tur in 1st year—maize and sannhemp in 2nd year—sugarcane in 3rd year.

Madras Province—

(*a*) *Rain-fed Crops* :

1. Cotton—jowar.
2. Cotton—groundnut.
3. Cotton—groundnut—jowar.
4. Cotton and Italian millet—jowar or Bengalgram.
5. Modan rice followed by horsegram, gingelly or samai—3 years fallow—modan rice, etc.

(*b*) *Irrigated Crops* :

1. Rice—plantains or betel leaf garden for 3 years—rice.
2. Rice—tobacco, gingelly or vegetables.
3. Rice—sugarcane.
4. Bajri, ragi, gingelly, maize, gogu or onions in early season—rice in main season—ragi, gingelly or onions in the late season of the same year—repeated next year.
5. Rice mixed with cotton, gogu or sannhemp—gingelly followed by jowar, Bengalgram or horsegram.
6. Cotton, jowar, tobacco, bajri, onions, ragi or gingelly in the hot weather followed by rice in the rainy season.
7. Rice followed by sannhemp or blackgram, greengram or pillipesara.

Mysore State—

(*a*) *Rain-fed Crops*:

1. Ragi mixed with avare or tuver—repeated.
2. Ragi mixed with avare—groundnut.
3. Early (kar) ragi followed by horsegram and niger.
4. Jowar followed by horsegram or horsegram and niger.
5. Jowar—cotton.
6. Jowar—cotton—groundnut.

(*b*) *Irrigated Crops*:

1. Rice—sugarcane.
2. Sannhemp or pulses followed by rice in the main season.
3. Gingelly in the early season followed by coriander. Coriander in the early season followed by white jowar, wheat, onions or Bengalgram in the late season (black cotton soils).
4. Tobacco—ragi with avare or tuver.
5. Tobacco—gingelly.
6. Tobacco—jowar or groundnuts or followed in same year by horsegram, gingelly or onions.
7. Rice—tobacco, groundnut, ragi or sannhemp—sugarcane.

[For the botanical names of the crops listed *vide* Appendix.]

CHAPTER XV

MIXED CROPPING

IN most parts of India the system of mixed cropping prevails, that is to say, instead of growing the several crops which a farmer has to grow in separate fields, each one field devoted to one particular crop, many such crops are grown together in one and the same field. These mixtures comprise grain crops and legumes very largely; for instance ragi and avare, jowar and tuver, wheat and peas and Bengal-gram, bajri with tuver or groundnuts. Many other mixtures are also general, in which oilseeds, pulses, fibre crops and vegetable crops, all enter as components. Mixtures consist mostly of only two crops but mixtures of three and four are not uncommon while in rare cases even more may be found. Such mixing of crops is to be found among all kinds of crops such as, dry or rain-fed, irrigated crops and even the permanent plantation crops.

One crop in the mixture is to be regarded as the major crop and one or more others are subordinate crops. The larger area is occupied by the former and the latter occupy rows therein, at different distances from each other depending upon the requirements of the farmer in regard to the particular crop and also upon its habit of growth.

The mixture may vary from only a sprinkling of one or more subordinate crops up to about 50% of each. Generally the subordinate crop is a pulse crop or oilseed like castor, which is of a spreading habit and which usually is sown in rows about 6′ apart; in a mixed crop this space is devoted to and occupied by the main grain crop. Even if the pulse crop is sown pure it will have to be sown at least 3′ apart, often more; so that the sowing of a grain crop in between is a case of utilising space profitably, which will otherwise remain vacant. The mixing of such a crop and sowing it at 6′ apart amounts therefore to sowing only one half the area which it would occupy as a pure crop, the other half being taken up by the main grain crop.

This full utilisation of space is secured in mixed cropping by mixing crops which will afford some shade along with those that require shade or will tolerate shade. Considerable castor is grown in garden cultivation along with ginger or turmeric, the latter crops fully occupying the ground under the castor. In the same way the large growing variety of tuver called 'garden tuver' is also grown in the place of the castor. Various beans may be trained on poles to which the growth of that crop is confined while all below other crops may be grown. Crops may indeed be grown on upright frames like tall screens, permitting the ground space to be cultivated with low-growing vegetables.

In plantations mixed cropping is very general, many kinds of fruit trees like cocoanuts, jack, mangoes, guavas, oranges, arecanuts, plantains, etc., all being grown as a promiscuous mixture. In other plantations the mixture may be systematic; thus, a few rows of oranges alternating with several rows of robusta coffee; tall standards furnished by shade trees carrying pepper bushes trained on them may alternate with several rows of Arabica coffee; and the well-planned mixture of plantains, areca, betel vine, pepper vine and cardamoms in the areca gardens of the malnad, in such a way that not an inch of ground is wasted.

A special feature of mixed cropping in respect of the annual crops is the fact that the components differ in their period of maturity, some maturing in a few weeks, others in a few months and still others taking longer, although all are sown simultaneously. Many vegetable crops are grown in this manner, some being picked as greens in 3 or 4 weeks, for the sake of their leaves, others left over for varying periods until their due time comes. Greens, coriander, fenugreek are grown in the midst of cabbages and kohl rabi, the former as early crop and the latter as the later ones. In field crops the ragi-avare mixture is the commonest in Mysore, the ragi matures and is harvested in 4 months while the *'avare'* is due to be gathered only 2 months later. The same is the case with jowar and tuver. In the cotton-navane (Italian millet) mixture, also a common one, the millet is gathered in 3 months while the cotton remains on the ground and is picked only some 2 or 3 months afterwards. The ground between the rows of the mixed crop allows of being hoed or ploughed after the main crop is removed which greatly benefits the mixed crop left behind.

Methods of Sowing the Mixed Crops

The crops concerned in the mixture are sown either by broadcasting or in rows. In the first case the seeds are mixed together in the proportion required, sown broadcast and given a light ploughing or harrowing to cover the seeds; or the seeds of one may be sown broadcast and the other in rows; thus ragi is sometimes sown broadcast and after it is harrowed in, plough furrows are drawn at regular distances in which 'avare' is sown. The mixing of all seeds together and broadcasting is a rather slipshod method and, though practised to some extent, is not common. The most systematic and interesting method is for the crops to be sown in rows either simultaneously or one after the other. Drill sowing is common in this method and it is managed with much skill. For example, where the twelve-tined drill is used with ragi, a one-tube drill (see for description under "Seeds and Sowing") is tied behind at the middle; one person feeds the seed bowl of ragi in front which sows the ragi, and another person walking behind holding the single tube drill feeds it with the *avare* seeds, so that both seeds are sown simultaneously but in rows and at regular

intervals, twelve rows of ragi alternating with one row of *avare*. In a three-tined drill for sowing jowar, the centre hole of the bowl may be plugged and behind this tine is tied the one-tined or single tube drill. In other drills with two or more tines, one or more journeys of the drill are used for the main crop, after which one hole of this drill is plugged and behind that blind tine a one-tube drill is attached which is fed with the mixed crop. In this way by plugging the appropriate hole in the multi-tined drill three, four or five rows of the main crop or other desired number of rows are made to alternate regularly with one row of the mixed crop. Thus three or five rows of jowar may alternate with one row of tuver, five rows of Italian millet with one row of cotton, and so on. The mixed crop may be sown pure or may itself consist of a mixture of several seeds, all of them being sown together in the drill row or plough furrow intended for the mixed crop. Mustard, niger, cowpeas, and various vegetables may be sown mixed in this manner in ragi or jowar fields.

In the case of irrigated crops mixed crops may be transplanted; stray seedlings of chillies, brinjals, or a few seeds of vegetable crops, or onions, etc., may be put in either along the water channels or promiscuously. In fields of irrigated Cambodia cotton, such plantings are common; elsewhere many pulses may be sown broadcast and then in furrows drawn at regular intervals, ragi or bajra seedlings may be transplanted.

EXAMPLES OF MIXED CROPS

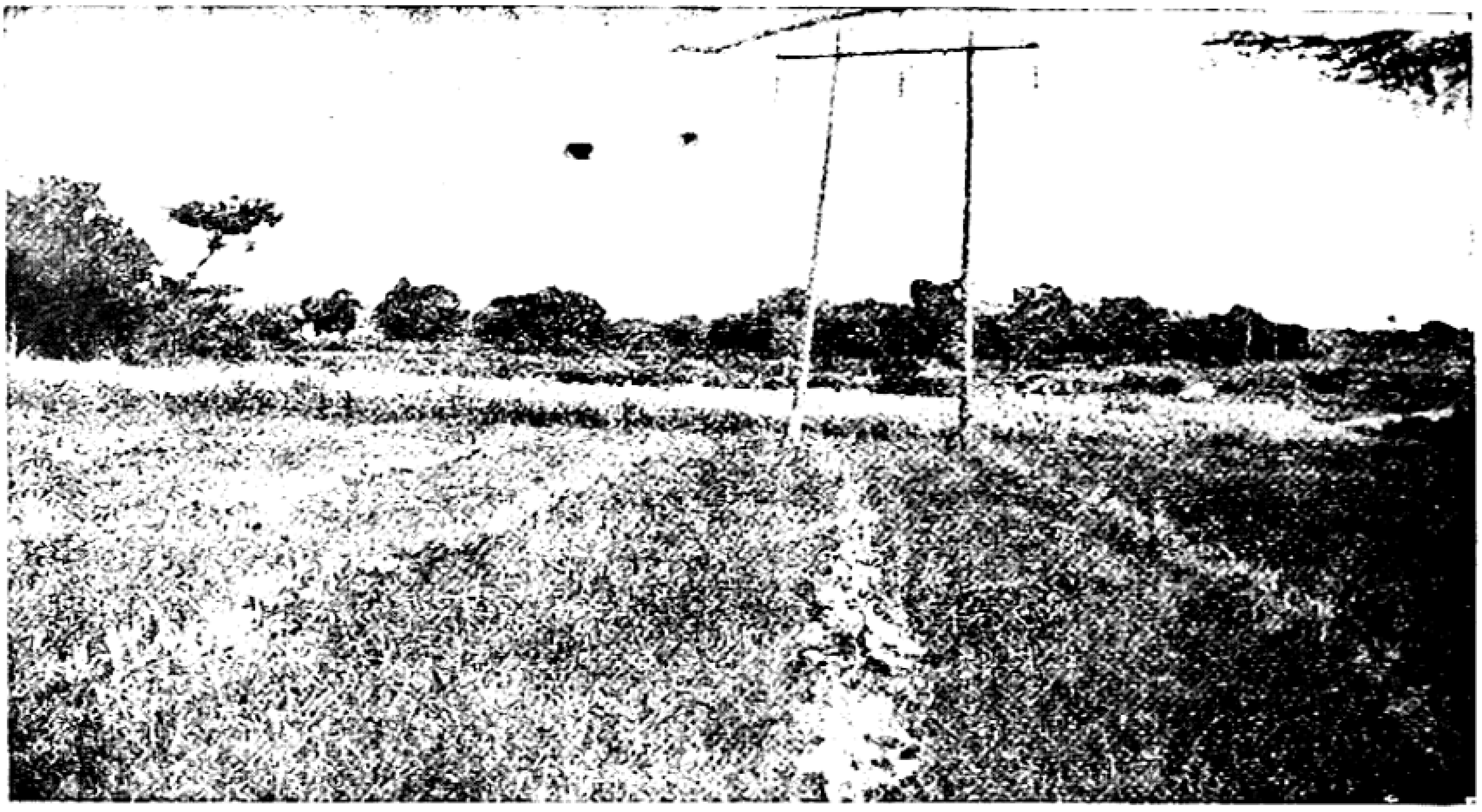
Numerous kinds of mixtures are to be seen in the different parts of the country and the following are some characteristic examples :—

Rice (in puddle cultivation), with other varieties of rice and jute; in dry cultivation, with jowar, maize, Italian millet, *Panicum miliare, Paspalum scrobiculatum* among cereals; tuver, blackgram, cluster bean, greengram, kesari among pulses; and cotton, jute among other crops.

Jowar, with other varieties, chiefly fodder jowar, with bajri, maize, rice, wheat and many minor millets among cereals; among pulses with nearly every one cultivated; and with castor, gingelly, safflower, groundnuts, cotton, indigo, linseed, mustard among other crops.

Bajri, with ragi, maize, jowar (fodder) among cereals; with nearly all of the cultivated ones among pulses; and with castor, gingelly, groundnuts, cotton, Deccan hemp among other crops.

Ragi, with wheat, jowar, maize, bajri, *Panicum miliare* among cereals; avare, tuver, cowpeas, sannhemp, horsegram among pulses; and castor, niger, groundnuts, linseed, Deccan hemp, mustard, cotton among other crops.



Mixed Cropping, Rows of avare (*Dolichos lab-lab*) in the midst of ragi (*Eleusine coracana*), a very common cereal-legume mixture, interesting in many ways, fodder jowar in the background.

Photo by Author

How mixed crops are sown. Through the twelve-row drill in front, twelve rows of the main crop (ragi) are sown by the man with the seed bag, and through the single row drill tied behind exactly at the middle, the woman sows the single row of the mixed crop (avare), so that twelve rows of ragi alternate with one row of avare. *Photo by Author*

Wheat, with barley, jowar, coarse rice, ragi among cereals; Bengalgram and wild peas among pulses; and mustard, rape, sarson, turnips, safflower and linseed among other crops.

Barley, with wheat among cereals; with Bengalgram, lentils, peas, berseem, tuver among pulses; and linseed, mustard, rape and sarson among other crops.

Maize, with rice (dry land), bajri, ragi, jowar and minor millets among cereals; with greengram, cowpeas, red gram, soybeans, berseem, *Phaseolus aconitifolium* among pulses and castor, sugarcane, potatoes, jute, groundnuts, etc., among other crops.

Cotton, with rice, ragi, bajri, jowar, maize and minor millets among cereals; red gram and most others among pulses; and cotton (of other varieties), groundnuts, castor, chillies, Deccan hemp, coriander, etc., among other crops.

[For the botanical names of the crops, *vide Appendix.*]

Principles on which Mixed Cropping is Based

There are many important aspects of mixed cropping, relating to the principles on which the practice may be regarded as based which deserve consideration and to which attention may now be drawn.

1. *Economy of Space, etc.*—On the face of it the main object is one of economy of space, manure, water and labour. The whole area of the field is profitably used; the work of ploughing and preparing the soil and later of interculturing and weeding are common to both, and so are manuring and irrigation. A variety of crops is therefore raised with the minimum of expenditure and on a smaller area, both of which are important practical considerations, while at the same time the requirements of the farmer for the different crops for his domestic needs are also largely met.

2. *Insurance against Failure.*—In the case of rain-fed (dry land) cultivation the mixing of crops amounts to a kind of insurance against a complete crop failure. If the rainfall is favourable throughout the season, both or all the crops benefit; if the rainfall is erratic then it happens that it benefits one or other among them. It is very seldom indeed that the season is so bad as to ruin all the crops. As a matter of common experience (in ragi cultivation, with avare as the mixed crop) when the grain crop is poor the avare or mixed crop is a bumper one and makes up. In a country of precarious rainfall largely depending upon dry cultivation for its sustenance, this should be regarded as practical wisdom of a high order.

3. *Yields from Mixed Crops.*—Many trials have been conducted to compare the yields under mixed cropping with those under pure cropping with certain crops. Yields have not always been in favour of pure cropping. In many cases the total from the mixed crops has exceeded those from pure crops on the same area; but even

if they should be only equal or even slightly less, the other advantages of economy and insurance against total loss should far outweigh this consideration.

4. *Mixed Cropping and Rotation of Crops.*—It is sometimes held that mixed cropping takes the place of a rotation. In some parts of Mysore the mixed crop ragi-avare is sown in the same field year after year without any rotation and similar practices exist in other parts of the country also. The point has been raised whether the mixed cropping of a grain with a pulse crop is not tantamount to or substitute for a rotation of the grain crop with a pulse crop which one would consider the correct practice.

The advantages of a systematic rotation of crops are of a varied character, as explained under "Rotation of Crops" and in a continuous cropping of the above kind only one aspect of it is brought out, *viz.*, the association of the legume with a grain crop. Whether a legume grown in mixture can confer the same benefit on the grain crops as one grown after it in a rotation is difficult to say, but even if it should, the need for a rotation will still remain in view of the various other advantages of a rotation. It must be stated however that a continuous cropping with the same mixture is confined only to certain small tracts and that the general practice in mixed cropping is one of rotation combined with mixed cropping; that is to say, a mixed crop consisting of particular mixture is rotated with another mixed crop with another and different set of mixed crops so that the mixed crop is taken as one unit in the rotation, in the same way as a single crop is taken as a unit in what is usually understood by rotation. The following are a few examples:—

Ragi and avare	followed by	groundnuts
Jowar and tuver	"	cotton
Cotton and Italian milet	"	Jowar or Bengal-gram or wheat

Wheat and peas—cotton or jowar—Bengalgram.
(For more examples see under "Rotation of Crops".)

5. *The Role of the Legume in the Grain-Legume Mixture.*—There are many experiments which go to show that grains grown in association with legumes are distinctly benefited. The associated legume can (if all the necessary other conditions are present) assimilate enough nitrogen from the air for its own needs and those of the grain crop grown with it. Other findings are that the nitrogen content of cereal grains and grasses increases by the association, that legumes and cereals have to be suited to or compatible with each other to benefit by the association and that the ratio of one to the other in the mixture has also some influence. On the other hand other experiments on the same subject can be quoted in which either the one or the other of the crops suffers, the growth of the legume being depressed more than the grain. The findings on the whole in favour of the benefit to the cereal certainly predominate but not

to the extent which may be deemed sufficient to establish the superiority of the mixture over the pure crop. It is probable that any accumulation of nitrogen by a pure leguminous crop may not survive the long hot weather fallow following the crop season so as to benefit the succeeding crop of cereal and that growing them in mixture is therefore the best method of taking advantage of the special property of legumes, but this is only a surmise. The definite superiority of one method over the other has therefore not been established.

6. *Utilisation of Manure and Water.*—Mixed cropping appears to be a more efficient and balanced utilisation of the manurial resources of the soil in any particular season than the growing of single crops, with or without rotation. This is based upon the facts that different plants absorb some plant food or foods in greater quantity than other plant foods, that a mixture of crops with varying depth of roots take up plant foods from different layers and that the absorption of certain plant foods is more in the earlier stages of growth in some crops and more in the later stages in other crops; all these are well accepted facts.

7. The same observation applies to the moisture content at different depths.

8. *Yield from Special Mixtures.*—It has been reported that the growing of indigenous cotton and American cotton as a mixture gives a larger yield of total cottan than the growing of pure crops of one or the other, and that a mixture of strains in other crops (like cereals) gives a better yield over a series of years than any one grown pure. These are somewhat against the recommendations usually made in favour of growing crop varieties pure. There can be no doubt that the produce of a mixture cannot be of a high quality on account of the mixture, but where the difference is not great or serious, then it is an advantage to grow the mixture. The reason appears to be that seasonal peculiarities affect the different varieties or crops differently, some being susceptible to hard conditions, diseases, etc., more than the others, making a mixture therefore a safer course to adopt over a series of years.

9. *Mixed Cropping in Relation to Crop Pests and Diseases.*—An interesting aspect of mixed cropping is in relation to crop pests and diseases. "The mixing of crops, so common in India" says Dr. Butler (*Fungi and Plant Diseases in India*) "has its advantages from this point of view, for, a crop of wheat, barley, gram, linseed and peas mixed together probably suffers less from parasites than five separate plots of these plants". Some crops in a mixture may act as a "trap" crop for pests and diseases, preventing them from crossing over to another crop and thereby protecting it. Jowar grown in between American cotton, or *Phaseolus aconitifolius* as a mixture in it, have both been found to act as a check upon the root rots of cotton. The mixture of American and indigenous cotton already referred to is said to be beneficial to both, as neither suffers

from the diseases peculiar to each, which affect them when they are grown pure. Among vegetable gardeners who usually grow many crops mixed, the belief largely prevails that some plants act as repellents of pests to others by their smell or bitter taste.

10. *Mixed Cropping a Disadvantage.*—Mixing becomes a serious disadvantage in certain respects. These are the following:

(*a*) Mixing may act as a disadvantage, as where horsegram or groundnuts are grown under castor; in order to keep down the castor semi-looper pest it is necessary to keep the ground well stirred and clean but in the presence of a mixed crop, this becomes impossible.

(*b*) It is impossible again to use any labour-saving implement or machinery on the field and this applies particularly to harvesting, which is an operation requiring much labour at a time when labour is in great demand. As one of the crops matures and has to be harvested much earlier than the other, the latter cannot be touched when the former is being harvested, and this 'selective' harvesting can be done only by manual labour. The system effectively precludes the introduction of a very necessary and urgent improvement as a reaper or harvester of even a moderate size suited to bullock draft, and this will mean that only small-scale farming with its all-important need for manual labour can be carried on.

(*c*) In the case of dry crops, it is a very beneficial dry farming practice to plough the field soon after harvest. This operation becomes almost impossible in the case of a field with a mixed crop on it. For example, if ragi is the only crop grown on the field then as soon as it is harvested, say in November or December, the field can be ploughed as there is generally sufficient moisture for at least a light ploughing; but where *avare* is grown along with the ragi, the latter is still on the field when ragi is harvested and will have to remain standing for another couple of months, by which time the ground will become too hard to plough. An important operation which greatly reduces the risk of crop failures in dry farming is thus made impossible.

To some extent this difficulty may be got over by adopting the system of 'strip' cropping, *i.e.*, where the two crops are grown not together but in wide strips of 10′ to 15′ in width, which will alternate with each other, so that a fairly wide enough strip will be available for the post-harvest ploughing; this however is equivalent to growing the crops in different fields, albeit very narrow, and is not 'mixed cropping' as practised now.

There is therefore much to be said both in favour of the practice of mixed cropping and against it. As long as the small-scale farming of the present time continues, the advantages of economy in space, water, manure and labour, and the insurance against total failures will far outweigh any disadvantage that may be adduced against it. The case for it also becomes stronger when it is remembered that it is not a system of continuous crop growing without

rotation but forms part of well-established rotations. When large-scale farming is attempted then the matter will assume a different aspect.

[For a full discussion of the subject, *vide* author's monograph on "Mixed Cropping" published as Vol. XIX, Part IV, of the *Indian Journal of Agricultural Science.*]

CHAPTER XVI

WEEDS AND WEED CONTROL

WEEDS comprise the plant growth in cropped land other than the crop which is cultivated; they form the unwanted vegetation on the land, which has therefore to be destroyed and removed, before they are able to do serious injury to the crop. They form one of the farmer's many enemies against which he has to wage perpetual war. Weeds are generally very hardy being often the natural vegetation on the land and are able to establish themselves and flourish under conditions in which the crop would only make poor growth; they are therefore powerful competitors with the crop against which the latter are at a great disadvantage. All the important preparatory agricultural operations and many subsequent ones have among their main objects the prevention or destruction of weeds, so as to enable the crop to grow without obstruction or serious competition. Cleanliness and freedom from weeds is a very important factor in crop production.

HOW WEEDS INJURE CROP

The various ways in which weeds cause injury to the crop are the following:—

1. Weeds occupy space which is required for the crop and thereby reduce the area available for the crop.

2. They take up space for their own growth, crowd the field and reduce greatly the space available for the proper branching and development of the crop, shutting out both light and air required for the crop.

3. Weeds compete with the crop not only for space, air and light but also for moisture and plant food in the soil. The moisture is generally the requirement which is in short supply and the competition of weeds for this all too insufficient supply is a great handicap to the crop.

As a matter of fact all these drawbacks act simultaneously and together and their combined effect is most prejudicial in the early stages of the crop. If this is not remedied at the very outset and from the time that the crop can be seen above ground, the harmful effect will persist and the grown-up crop later on will show signs of this initial setback. Moreover at this stage the crowding of the plants and the competition for space, both above ground and below ground, is a most harmful feature and this applies whether the crowding is to the young crop itself as the result of thick sowing or to weed growth or as is most often the case to both. This overcrowding and struggle for space, moisture and plant food whether by crop or weed has to be remedied from the very earliest stage by a thinning out process, severe or moderate as the case may require.

In this operation, the removal of weeds and superfluous crop seedlings both result.

4. Some weeds may act almost like a poison and will seriously injure both growth and yield of crop. A striking instance is the spreading of the grass 'hariali' (*Cynodon dactylon*) in cotton fields which is inimical to the cotton crop and has to be thoroughly and systematically removed or kept under control.

5. Most weeds are extremely hardy and with the special attention given to the crop, in which they share, they may grow so fast and well as to smother the crop.

6. Many weeds, if left on the field in the midst of the crop, grow at the same rate and mature at the same time as the crop and may be harvested and threshed along with the latter. The result will be an admixture of their seeds with the produce of the crop. Many grains and pulses are subject to this drawback, and if the weed seeds should happen to be of the same size as the grain or pulse, it will be very difficult to remove them from the mixture. Where no special effort is made to clean the produce then the proportion of weed seed may be considerable and both value and quality of the produce will be lowered. If the weeds seeds should have any objectionable smell or taste, or be poisonous (like *Euphorbia dracoculoides* in barley) then it makes the admixture very serious. Even with careful and timely weeding many weeds will escape destruction, but where weeding has been imperfect a very large number will survive and prove a real danger.

7. Some weeds may mature earlier than the crop and shed their seeds in the field which will then become very badly infested in the following season and may persist for many seasons. In fact, it is a common saying that "one year's seeding is seven years' weeding", and this summarises very aptly the result of carelessness in weeding. When it is remembered that some weed seeds are extremely small and are borne in enormous numbers, the truth of this saying can be better appreciated.

8. There are some weeds which survive the harvest and once the crop is removed and the field left entirely to them, branch out and make luxuriant growth, mature and shed seeds in vast numbers. The weed called 'Anne soppu' (*Celosia argentea* Linn.) is of this kind in ragi fields and once it makes its appearance in the field it is very difficult to get rid of, as it increases from year to year, the seeds being so numerous that a very large number of plants will survive in the crop even under very careful weeding.

9. Some weeds like the 'touch-me-not' (*Mimosa pudica*) especially and sometimes the khaki weed (*Alternanthera echinatus*) spread in gardens and are very difficult to get rid of. The former has thorny stems and covers the ground like a carpet, making it very painful to walk barefooted through it. In some regions the weed has invaded all vacant places like road margins, waste land and common grazing grounds as well and has become impossible of control.

The latter has come in rather recently but has spread very rapidly. It has fine rosettes of thorns at the nodes, on which walking with bare feet is painful. To the same class also belongs the *Tribulus terrestris* whose fruits have very sharp thorny excrescences, on which walking with bare feet is impossible. Some kinds of bush vegetation which have become pests overrunning large tracts of uncultivated land and which are difficult to eradicate are the lantana and prickly pear. These were originally introduced as effective hedge plants and the former as also an ornamental flowering plant but they have become so well established in their new environment that they have overrun all waste places, pastures and jungle land and multiply in such a manner that they are almost impossible to control by the ordinary physical or tillage methods.

A somewhat similar pest against which it appears impossible to contend is the water hyacinth, especially in Bengal, where it covers every kind of pool, tank, lake or other water spread, chokes up canals and waterways and is the counterpart on water of the lantana and prickly pear on land.

10. Many weeds may harbour pests and diseases as host plants and form centres of infection for adjacent cultivated crops though the latter itself may be free. Weeds of this kind are usually confined to the field bunds and margins, which are seldom clean and on which weeds harbouring these pests may be growing in the off-season when there is no crop on the land and from which they may pass on to and infect the crop when the latter is sown.

11. A weed is sometimes defined as a crop plant in the wrong place. This really means that even plants which ordinarily belong to the class of cultivated crops may sometimes be regarded as a weed, *i.e.,* a plant not wanted where it may be found. When any particular crop is intended to be grown pure and unmixed with any other crop or variety of the same crop then the presence of any of the latter becomes undesirable, because the produce is likely to become mixed which may reduce the value or quality, and may require special cleaning and separating out of the mixture. A red or coarse rice, for example, in a crop of white and fine rice is an undesirable mixture, an early-maturing rice in a late-maturing rice is an undesirable mixture and so on. Similarly in a variety of cotton like the D.A. for example the local variety may be a mixture (to be avoided) and *vice versa,* and this remark will apply to even different strains in the same variety. If the mixed plants can be made out by any conspicuous outward character, then it will have to be 'rogued out', the 'rogues' being indeed weeds in such fields. A very troublesome mixture of wild rice arises in rice fields in the Mysore malnads which have to be rogued out in enormous numbers, as soon as they head out when they can be easily distinguished. The grains have the habit of shedding completely and if the plants were not removed in time, *i.e.,* before maturity, they will become the source of extensive weed growth in the following season.

12. Some weeds are parasitic and come in a special class. These appear somewhat late and after the usual weeding operations are over. Examples are *striga* in jowar and sugarcane and *orobanche* in tobacco. They grow in close association with the crop plants, draining their nutrients and weakening their growth. The orobanches moreover come up and show aboveground after much mischief has already been done and only when they are due to flower and set seed. A somewhat similar pest is the 'dodder' (*Cuscuta trifolii* and other spp.) which attacks and is parasitic on clovers and legumes and is very difficult to eradicate.

How Weeds Spread

The various ways in which weeds spread and find their way into the soil are the same as the well-known methods by which vegetation in general spreads, whether it be through seeds or vegetative parts. Many weeds escape destruction in the field by the various tillage and hand-weeding operations and mature and shed their seeds in the field, some doing so before the crop is harvested and some after. This is the most important way in which weeds gain entry into the field and where weeding is not thorough or cannot be thorough as where crops are sown broadcast instead of in lines, weeds increase so much as to require special methods to get rid of them.

Many weeds get into the soil through the cattle manure or town wastes and sweepings which are applied as manure to the soil. This is a fertile source and some of the newly introduced weeds certainly owe their origin to this source. Many seeds especially those with hard glossy coats are not destroyed in the digestive tract of cattle and sheep and are voided with their germinating capacity unimpaired, so that when the manure is applied to the soil the seeds are able to germinate with the rains. Many seeds however rot and lose their germinating power in fermenting or old manure and it is always advisable for this reason among others, that manure should be well rotted. In sheep manure the risk is greater because it is applied fresh as in sheep penning or is not rotted even when old as it is fairly dry. Manure from cattle and sheep returning from pastures or jungle grazing grounds may introduce many weeds into the fields which may not be seen roundabout. Seeds may likewise adhere to the bodies and limbs of cattle and sheep, through the special adhering adaptations they possess and be introduced into the soil where the animals may lie down or move about.

Weeds may be introduced through the excreta of birds, which eat fruits and berries, the seeds of which are practically fresh when excreted. Many thorny shrubs, bushes and large trees are spread in this manner (the lantana among others); annual weeds on the farm introduced in this way are however few.

The wind as is well known is responsible for the spreading of many kinds of weeds, which possess special appendages to help them in this aerial transport. A lot of seeds come into the field through this agency from field margins and waste land foul with weeds, from which they are easily wafted by the wind.

In rice fields many kinds of water weeds, more especially the sedges and many water grasses are brought in by irrigation water. There are tracts where the yearly increase of weeds from channel water, foul and often choked with sedges and reeds, is so great as to become a serious menace to rice cultivation. It is a remarkable fact that many weed seeds retain their vitality even when they have been submerged or buried in the ooze for many years, and can sprout when the tank silt or ooze even from the sea bottom is brought up and spread on the fields. A somewhat noteworthy observation is the fact that when the Willingdon Island was formed at the mouth of the Cochin Harbour from the mud dredged out in making the ship canal, a rich and varied vegetation—all quite new to the neighbourhood—but with their home probably on the far-off high mountain range from which the waters of the Alwaye river come down, sprang up and is found luxuriating on the island.

Though the spreading of weeds is mostly through seeds, in the case of certain troublesome weeds, the spreading is through their vegetative parts also. The chief among these are the grass hariali (*Cynodon dactylon*) and the sedge, bulb grass (*Cyperus rotundus*). In these cases the propagation is by the additional method of stolons or underground stems; the *hariali* grass can be easily propagated by planting cut pieces of the stems which will readily root, and the bulb grass likewise creeps along, rooting and forming independent plants as it spreads. In both cases curiously enough the ordinary method of ploughing has the effect of multiplying them, far from destroying them, because the parts torn off and separated from the parent plant root and begin to grow as separate new plants and therefore tend to increase. Special methods are needed for getting rid of them, as will be explained.

Methods of Control

The methods of controlling weeds may be dealt with under two heads, *viz.*, (1) Prevention, and (2) Destruction.

1. *Prevention*

As the various ways in which the seeds of weeds gain entrance in the field have already been indicated, the method of prevention will comprise such practical operations as will shut out these means of ingress. For instance, it is of the utmost importance that weeds are prevented from maturing and setting seed, by timely destruction. This applies not only to the field but also to the field bunds and margins which have to be kept clean. Manure should as far as possible be well rotted, and street sweepings and refuse should be

applied not directly on to the land but should be dumped into the manure pit where some amount of fermentation and composting may take place which will destroy the vitality of the seeds of some at least. In fact, composting weeds, in this way, is a method by which they become not only harmless but also are turned to good account. The seeds of the crop to be sown should be closely inspected and all mixture of weeds and other extraneous plants should be cleaned out as thoroughly as possible. It may not be possible in practice to deal with the other ways in which weed seeds get into the field so as to shut them out; through the agency of animals, of wind and water, weeds will continue to gain entry into fields and nothing can be done in the way of prevention. In fact, preventive methods of weed control have only a limited use in practice and for effective control only methods of weed *destruction* will have to be resorted to.

Reference may however be made to a method which is both preventive and destructive; this consists in the removal of all weed growth whether bush, shrub or low-growing vegetation on all fields, field margins and open places in and around any village or defined area, by individual or by joint work. Particular kinds of weeds or noxious vegetation are perpetuated, even though individual farmers may keep their holdings clean, because others may not do so on their own fields and these, together with the growth on the waste lands or common grazing grounds, become fertile sources from which fields cleaned at great expense may be invaded. Such pests are amenable only to joint action by all the villagers; and in certain countries this obligation is enforced by legislation for controlling weeds and noxious vegetation, which specifies the particular weeds concerned and the penalties for default. The prickly pear, lantana, touch-me-not, and similar pests have to be dealt with only by some such special measures. The "Noxious Weeds Act" of Coorg against the spread of lantana, is an instance of such legislation and is perhaps the earliest to be enacted in India in recent times.

2. *Weed Destruction*

In ordinary practice the commonest and most effective method of control is the removal or destruction of weeds as they come up or at different stages in their growth. Various methods are adopted for this purpose but the most important are the tillage methods such as ploughing, cultivating, harrowing, heoing or interculture, etc.

(*a*) *Weed Control by Tillage.*—A good proportion of the control can be accomplished firstly during the preparatory cultivation, *i.e.,* before the crop is sown. The ploughing destroys or turns under such weeds as may be already growing in the fallow field, exposes their roots and kills them. The second ploughing or cultivating continues and carries on the work further. It is essential that some time should elapse between successive operations, which should be sufficient to make more of the weed seeds to sprout, when they are effectively destroyed by the tillage. This is necessary because all weed

seeds do not sprout at the same time, either because they are different from each other in kind, or lie at different depths or enclosed in heavy clods, and these repeated operations give a chance to all the weed seeds to sprout and be destroyed by the tillage. It will be seen that weed seeds have to be made to sprout and then only can be destroyed.

It is also essential that the uprooted and destroyed weeds should be gathered together and removed from the field or burnt on the field after they are dry enough. The cultivators and harrows all help in this work of bringing up the remains of the weeds and gathering them together. Such removal or burning is very necessary because many weeds can multiply vegetatively and may root from their cut stems and if left on the field will neutralise all the cleaning work accomplished by these implements.

Good work can be done by the mouldboard ploughs and the bladed harrows (*kuntes*) described under implements of tillage; both these cut the weeds at some depth and such cutting at a depth is necessary because some kinds of weeds, if they are not cut low, can send out shoots from the cut ends and become better stimulated to growth.

Weed destruction has to be continued even more vigorously and carefully, *after* the crop is sown. One important aid to this operation consists in sowing the crops in rows and not broadcast. Cultivation between the rows (interculture) by means of bullock implements is possible in the first method, which is quicker and cheaper than hand-weeding. In broadcasted crops some kind of bullock implement (usually the country plough) can be used but the work is neither as quick nor as efficient as with regular interculture tools. Interculture for weed destruction should begin at the earliest possible opportunity, as soon as the seedlings appear above ground and the braids are visible. The removal of their competition with the crop at this stage is of great benefit to the crop. Weeding is generally done between the rows, but should cover the whole of this space and work very close to the rows of the crop also. It should be repeated two or three times at intervals of a week or ten days, in order to destroy those which may have appeared in the intervals and those that may have survived the previous weeding. Much alertness is required and the interculture should be prompt and timely, because the soil should have the proper content of moisture without being wet, for facility in the use of the implements and the correct time is therefore of importance.

Weeding with bullock implements is done also within the rows of crop, in order both to destroy the weeds therein and to thin out the crop itself to the proper density. The bullock implements used for this purpose are generally very light hoes which have pointed or spiked or chisel-shaped points, two or three in number set in one line. These uproot the weeds which lie in the track of the teeth, the space between the teeth being left untouched. The toothed hoes have the advantage that they can be used across the rows also, just

once, when they do considerable thinning of the crop itself. The hoes are light and they should work to a depth of only an inch or two. A hoe of a different kind is the bladed hoe which has a blade instead of points or spike whose length is only slightly less than the space between the rows; at each journey this hoe fully works the space between the rows and even does a certain amount of earthing up of the rows. This is also a light hoe and is suited for work at a very early stage. It cannot of course be used for working across the rows, except in the case of crops which have been dibbled or transplanted in fairly wide squares chessboard fashion.

At a later stage and in the case of jowar especially and of cotton (in certain tracts) a light plough may be, and is, used to do the same work. This will uproot weeds which have become fairly well established, but will leave considerable space unworked; it has however the advantage that where crops have been sown in rows, it can do much earthing up of the rows and also leave a deep furrow alongside the row, which will help to hold rain-water. In orchards or gardens it is the country plough which is used for weeding, where the planting is regular and the inter-spaces large, or hand-digging tools where the garden is irregularly planted.

Weeding cannot be done thoroughly with bullock implements alone but will have to be supplemented by hand-weeding. This is done usually at a later stage and effectively removes even well-established weeds. In such cases it is important that the weeds are cut or scraped off quite below the surface, otherwise, many of them will branch out and grow again as already mentioned.

Weeds in Rice Fields.—These observations apply in the main to all crops other than puddle-grown rice. In rice fields, the general method is only hand-weeding; but weeding by bullock hoes is usual in some sections, as in the malnads. The hoes then work in the submerged puddled soil and always bring up a good number of rice plants along with the weeds. As the seed rate is very high in these parts this degree of severe thinning does not matter. Weeding will have to be more thorough in broadcast rice fields than in transplanted fields, as the weed growth is much heavier in the former. Floating vegetation like algal growth and others sometimes increase very much in rice fields and cause trouble. These can be controlled by draining off the water completely from the field and leaving it in that condition for a few days. This weakens aquatic growths too much for them to revive again when water is let in as usual and the flooded condition is restored.

Hariali on Black Cotton Soils.—The removal of *hariali* or *dub* grass in black cotton soil fields is a special problem and will demand costly and strenuous labour. It is a deep-rooted weed, spreads rapidly and can live through the hot weather in these rich black cotton soils. The common and most thorough method is to dig the fields in the hot weather months of April-May, turning up very heavy clods to a depth of 1′. These clods are allowed to dry completely in the

hot weather and along with them the *hariali* grass which should all have been uprooted completely if the depth was not less than 1′. The clods are then broken and the *hariali* grass roots which are set free from the clods should be gathered and burnt. For some four or five years this will keep the field sufficiently clean, after which the process will have to be repeated. This is obviously a very slow method and with the high cost of manual labour is gradually being given up. The same work can be accomplished (though not so thoroughly) by means of heavy ploughs, and specially large wooden ploughs were being used for the purpose until at the present time these have been replaced by large size iron mouldboard ploughs. The work is hard and will require some five to six pairs of good bullocks, but more land can be covered and at less cost. The ploughing can be more advantageously carried out by means of tractor ploughs but the tractors required for the purpose should be heavier and have much more power than those ordinarily used for farm work. After the fields are ploughed, the subsequent operations are the same as in hand-digging. There is no other alternative to this kind of digging out (or extra deep ploughing), slow and costly though it is.

Bulb Grass.—The bulb grass (*Cyperus rotundus*) is another troublesome weed, especially in garden cultivation and rich land, which also requires special methods, particularly deep digging in the hot weather and complete removal of all the grass bulbs from the field. If any bulb is left, then it will very soon begin to grow and extend, giving rise to more bulbs as it creeps along. In the cultivated field itself, the grass will have to be cut frequently as it makes its appearance above ground. This will have the effect of preventing the grass from developing bulbs underground and to that extent weakening its powers of multiplication.

(*b*) *By Flooding.*—In such garden soils, if the supply of water will admit of it, then a crop of rice may be taken with advantage, as a means of destroying this and other weeds which cannot survive the submerged condition. Orobanche in tobacco can also be controlled by this method of submersion and puddle cultivation of rice.

(*c*) By *Rotation of Crops.*—As a matter of fact, in the ordinary systems of rotation of crops a cleaning crop like some tubers or root crops or a crop which will in addition spread and cover the ground quickly like groundnuts will have to form part of the rotation, so that the digging necessary for harvesting these crops acts as an effective measure of weed control.

(*d*) *By Manuring.*—It may sometimes be possible to so stimulate the crop by the application of quick-acting manures like oilcake or sulphate of ammonia so that it makes quick and luxuriant growth and to some extent smothers the weeds under its shade or at least enables it to withstand the competition better.

Closely related to the above method of utilising shade is that of heaping up manure or sweepings over patches on which weed growth in the crop season may have been serious. It will be found

that when the time comes for disturbing the heaps and spreading the manure many of the grasses and other weeds have either perished or become bleached and weakened and can be easily destroyed in the ploughing. Weeds on the whole are a difficult problem and the farmer has to wage a perpetual war against them and no amount of carefulness will be too much. It will generally be a wise plan for the farmer to carry a knife or cutlass with him in his rounds and cut down any large weed growth wherever he finds them. This will prevent them from growing up and seedling, which is an important consideration in respect of weed destruction. A great deal of trouble in the subsequent season can thereby be avoided.

(*e*) *By Drainage.*—Some weeds are peculiar to poorly drained fields, in fact lack of proper drainage encourages a particular kind of flora and these can be controlled by improving the drainage.

Special Methods of Weed Destruction

The above methods of weed destruction are what may be termed the ordinary physical methods usually followed in field husbandry and they are universal. There are however other methods of weed destruction which are of a special character, to which reference may now be made. These comprise: (1) singeing or burning by means of 'flame throwers' or similar appliances called "Sizz weeders" suited for large-scale mechanised operation; (2) spraying or dusting or smearing of various chemicals which have the property of killing vegetation; (3) the introduction of appropriate insect pests which will feed upon and destroy the unwanted vegetation without touching the crop or the "biological method", as it is sometimes called.

1. *Singeing.*—The method of destruction by burning or singeing is stated to be coming into use for burning up weeds in between the rows of cotton in the Southern States of the U.S.A. The flame is thrown to a distance of even 20′ and is produced from atomised oil under pressure. The machines carry up to four fire throwing hoses and are able to handle that number of rows in every journey. The method appears to be not one of complete killing of the weeds but one which destroys them partially and puts back their growth, so that the crop soon gets the upper hand and becomes sufficiently well grown to smother the weeds. All weeds however are not equally susceptible to destruction by the method and while some are killed out many are stated to be unaffected.

2. *Chemical Weed-Killers.*—Among chemical weed-killers many have been known for a very long time and have found application in a limited way for the killing of unwanted growth on lawns, garden paths, road margins and the like. There are many substances known to have this property, *viz.,* sulphuric acid, sulphate of iron, arsenite of sodium, sulphate of copper, sodium chlorate, borax and even common salt. The action is more or less selective and the killing is confined to particular kinds of weeds. The author has tried some of these and has found that they merely

scorch vegetation, which comes up again after a time. A saturated solution of common salt was found to scorch 'touch-me-not' to killing point, but growth started again with the rains. Sulphate of copper has been used sometimes to kill algal growth in ponds and canals successfully. Obviously all these are of limited application both on account of their small effect and of the comparatively high cost.

Some of the tar-distillates and allied products are however powerful weed-killers and deserve attention where large stretches of noxious vegetation have to be cleared. For killing large trees a proprietary product of the name 'Atlas tree-killer' is a powerful material and is in use for the destruction of large trees: even trees which are not easily killed by "ringing" such as those with a latex in the bark, succumb to this product. It is also easy to apply, as it has only to be smeared or painted over a small patch of the scraped and exposed bark tissue.

A rather interesting new herbicide chemical for which great claims are made is the compound called dichlorophenoxyacetic acid or 2·4 D for short, and put up for use under the commercial name "Weedone". It is claimed that when sprayed on to plants it penetrates the tissues down to the roots and effects complete destruction, that it is non-poisonous and non-corrosive or irritant to the skin, and that it is selective in action, *i.e.,* killing only weeds like docks, thistles, rakwort buttercups and other broad-leaved plants without injuring cereal crops. A gallon of the 'Weedone' is said to make 400 gallons of the spray solution. The pure 2·4 D itself is said to be used at the rate of 1 lb. dissolved in 100 gallons of water per acre. Some spectacular use is reported to have been made of it in Australia and in California, where rice fields have been sprayed from low-flying aeroplanes. What particular Indian weeds it will destroy without injuring crops is not known as no trials have been reported. Recently both this compound and several others have been put out as proprietary products under a variety of names such as agroxone, fernoxone, dicotox, etc., which indicates perhaps that the method is being found useful. Very few trials in India have however been reported, in regard to weeds infesting cropped land. On the Coffee Research Station in Balehonnur (Mysore State) many of these products have been tested, on the troublesome weeds in that tract, *viz., Ageratum conyzoides, Bidens pilosa, Mimosa pudica, Gynura angulosa* and others and it is reported that they all have a destructive effect on these weeds. In and among growing field crops their use should be considered very limited, as several broad-leaved crops are also grown with the grain crops as mixed crops, which will be destroyed along with the broad-leaved weeds, and as there is always the risk to broad-leaved crops on neighbour's fields, onto which the spray or dust is likely to be wafted. Where solid blocks of weed infested areas are concerned like *mimosa* covered areas or water-hyacinth covered water surfaces, they may find much

scope for profitable use. It is reported, as a matter of fact, that both in the case of the lantana and the water-hyacinth, some of the 2·4 D preparations were found very effective; and that they had no deleterious effect on the freshwater fauna of hyacinth covered water (*Philippine Agriculturist,* Vol. XXXIV, No. 4).

3. *Biological Methods.*—The most remarkable instance of the destruction of noxious vegetation falls to the credit of this method. It relates to the wholesale destruction without any special effort on the part of man of vast stretches of prickly pear (*Opuntia dillenii*) first in Australia and then in South India, in a manner that for quickness, permanence and cheapness is beyond belief. The destructive agent concerned is the cochineal insect *Dactylopius tomentosus.* It was introduced into South India some twenty years ago and became an immediate success; it spread over all the prickly pear areas and was so thorough in its action that prickly pear hedges, thickets and jungles and individual clumps have all been destroyed leaving little or no trace in the country, and apparently never likely to show itself again. It is still more remarkable that the insect did not pass over to any other kind of vegetation or crop, either when the pear was being destroyed or even after this was all destroyed and there was no more for the insects to feed on. The only effort which it involved was for some one to carry a few branches of the infected prickly pear or even just one leaf and throw it on to the hedge or group to be destroyed. The same effect of total destruction of the prickly pear was also brought about by the moth-borer *Cactoblastis cætorum,* an insect likewise confined to cactus alone and not passing over to other vegetation.

The lantana was likewise attempted to be destroyed by a fly (*Agromyza lantanæ* Frogatt), which is found to attack and destroy the flowerheads and berries and thus prevent seed formation and multiplication. It was found however that the destruction was not material, and as a control measure it did not amount to much. As a matter of fact the fly has now been found to be fairly widespread in India, with the lantana nevertheless flourishing extensively, evidently quite unaffected by the fly damage.

In addition to control by insect pests, it may be possible to utilise some forms of vegetation for controlling others. It is known for example that in nature certain plants will not grow in association with each other, either because one will smother the other, or the shade of one is inimical to the other or on account of some poisonus exudation from the roots or other similar obscure cause. The "touch-me-not" was indeed attempted to be controlled by a quick-growing grass which spreads like a thick carpet crowding out the former and keeping it from spreading, if not killing it out. This is found to happen only in particular situations where the conditions are very favourable to the grass which dies out in the hot weather. The study of the association of plants in nature may disclose antagonisms which may prove useful in the control of weeds.

CHAPTER XVII

DRY FARMING

THE principles and methods of the conservation of soil moisture assume great importance in practice in "Dry Farming" or the cultivation of crops solely under rain-fed conditions and in a special manner where the rainfall is low or precarious during the crop season. Satisfactory plant growth will be impossible unless an adequate supply of water either by irrigation or by a sufficient and well-distributed rainfall is available. Much mitigation however may be effected and moderate crops at least can be secured by the adoption of 'dry farming practices, which really mean to a large extent only the conservation of soil moisture.

These practices aim firstly, to put the soil or the field in such a condition that all the rain will soak into it and little or none will be lost by surface flow, secondly, to prevent loss of soil moisture by surface evaporation and transpiration through weeds and thirdly, to help the capillary rise of the soil moisture to the sprouting seeds and the root zone of the crop,—in fine, to increase the gains to the soil moisture and reduce the losses therefrom and to retain the moisture where it is needed by seed or crop, by methods based on principles already dealt with. This is achieved in practice by the following methods :—

1. Laying out the fields in level strips, that is, by reducing the slope as far as may be practicable. This will mean a certain amount of terracing, if any large area is involved and the slope is much. If necessary the fields should be divided into smaller ones, so that they may be fairly level. Low bunds should surround the field so that rain-water may to some extent be impounded; a fairly good bund should certainly be put up across the lowest side, both to impound the water and to break its force and prevent it from eroding or scouring the surface. On large stretches of black cotton soil fields, bunds, sometimes elaborate and stone-riveted, are usually put up and provided with a suitable outlet to carry off the excess without eroding the field. Across cocoanut gardens grown in shallow valleys, bunds are put up to impound the water of the surface flow, which is made to fill and saturate one part of the grove and then overflow into the next. These are excellent dry farming practices and should be adopted generally. Where rains come in sudden and heavy bursts and may create scours in the field in spite of reducing the slope, then it will be advisable to cut drains across the slope and above the field, in order to break the force of the flow.

2. The fields should be ploughed up immediately after harvest, or at least cultivated fairly deep, and left in that condition, so that the rain-water of the very first rains will soak into the soil better than it will, if the soil was hard and compact. It is possible

that such ploughing conserves the moisture already in the soil as well, before the rains begin, but even if this should be doubted or the saving considered too insignificant, its effect in making the rains soak better into the soil is very real and of undoubted advantage. The ploughing should of course be across the slope in all sloping land and not along, so that scours may be prevented and the rain-water be held up better.

3. With every shower of rain thereafter the soil surface should be ploughed or harrowed both in order to bring the soil into a suitable physical condition for sowing and also for eradicating weeds as they come up and thereby prevent loss of soil moisture.

4. When the field is nearly ready for sowing, the levelling boards or logs may be worked in order to secure a firm seed-bed and one into which soil moisture will rise better by capillarity so that the seeds can have the best chance of germinating. The levelling board or log should however be followed by a light harrow to restore the soil mulch and prevent drying up of the seed-bed.

5. The crops chosen for dry farming should be such as are reputed to be drought-resisting. The ordinary dry land grains are generally of this type, such as ragi, jowar, Italian millet, bajra, etc., and ragi may be perhaps considered the best for this purpose. A deep-rooted crop like one of the legumes 'tuver' (*Cajanus indicus*), avare (*Dolichos lab-lab*), etc., may also be selected to be grown pure or with more advantage as a mixed crop. These latter crops will tap zones of moisture not accessible to the shallow-rooted grain crops and flourish even though the latter may suffer for lack of moisture.

6. The sowing should be preferably in rows, for facility of frequent and efficient interculture later on, by bullock implements.

7. The seed rate should be somewhat low, so that a crowding of plants may be avoided especially in the seedling stage, which may mean a greater competition for and depletion of moisture at this stage. For the same reason a comparatively thin stand will be secured. A good start for the young crop is also desirable and this can be secured by mixing the seed with good cattle manure and then sowing.

8. If the surface soil is very loose and powdery, a certain amount of packing or pressing of the soil (in imitation of tamping) should be arranged or a herd of sheep driven round and round over the sown field as is the custom in certain parts of the Mysore State in fields sown with ragi.

9. Interculture should commence at the earliest opportunity between the rows and even across, to remove weeds and thin out the stand. This is a very important operation and a crowding of plants at this stage and neglect to weed and thin out in time will considerably retard growth. Such interculture should be frequent, both as a measure of weed control and of preservation of the soil mulch.

10. In addition to these tillage methods the soil of the field itself should be improved in its moisture-holding capacity and fertility by additions of tank silt and clay and moderate doses of cattle manure, compost, green manure and similar organic manures.

It has been found that the quantity of water required by a crop (used up in transpiration) is less per pound of dry matter produced, if the soil is fertile, *i.e.,* rich in plant foods, than when the soil is not so. Very striking data which prove this fact are furnished by Widtsoe (*Dry Farming*) from experiments conducted over many years in Utah. For example, using maize (or Indian corn) as the crop, "on a soil naturally fertile, 908 pounds of water were transpired for each pound of dry matter produced; by adding to the soil an ordinary dressing of manures, this was reduced to 613 pounds, and by adding a small amount of sodium nitrate it was reduced to 585 pounds". The importance of enriching the soil has therefore to be stressed in dry farming quite as much as in ordinary farming, more especially as the increasing and conservation of soil moisture is the primary and most important aim in Dry Farming. The repeated ploughing, cultivating and harrowing of the soil necessary and recommended from the point of view of soil moisture and weed control, have the further effect of liberating more plant foods in the soil and helping it to utilise the moisture more economically or to greater purpose. In Indian soils it may be advantageous to use cattle manure, green manure or compost, because these serve the double purpose of improving the water-holding capacity of the soil and of adding fertility at the same time. It is an interesting fact that in certain parts of Mysore it is the practice in dry farming to mix the seed with well-powdered old cattle manure and then sow it. In addition to helping in a better distribution of seed this has the effect of giving an excellent start to the seedlings and of sustaining such growth by the provision of plant foods just where wanted in the soil.

11. *The Campbell System of Dry Farming.*—In this connection it may be interesting to recall that in addition to the ploughing after harvest mentioned above a special form of preparatory tillage enjoyed some vogue and great publicity in the U.S.A. some years ago (both of which were however short-lived). This consisted in deep and thorough ploughing and discing to break the clods and then in *packing or compacting* the subsoil with a "Campbell subsurface packer". This was an implement which, as its name implies, compacted and pressed the ploughed mass, and this was effected by means of a series of blunt discs (unlike the dished discs of a disc harrow) mounted like the rings or sections in some types of rollers. After the subsoil was pressed and packed in this manner, the top surface was kept frequently harrowed. It was claimed for this set of operations firstly, that the soil was put into a condition in which it would absorb all the rain (or snow), secondly, that a moist layer was produced into which the seeds would eventually

lodge and find favourable moisture conditions brought about by the rise of capillary moisture from below through the compacted layer and thirdly, that the loss of soil moisture will be prevented by the mulch produced by the frequent harrowing of the top soil. Part of the method also consisted in cropping the land only every other year, the field being left in the above condition during the whole of the fallow year. It is not known if the method was put to any systematic tests; it has not been taken up as a general practice and is now practically forgotten. The author visited the farm in Holdridge, near Lincoln, Nebraska, U.S.A., of Mr. Campbell, the originator of the method, who showed him round and explained his methods at the time. There was a young crop of maize growing on the farm, but although it was somewhat better than the crop on the adjoining fields there was nothing remarkable about it, except that it was a marvel of clean cultivation. The moisture below the well-stirred surface of the fallow land was however striking.

A 'subsurface packer' was later got out and used on the Hebbal Farm of the Mysore Department of Agriculture, but it was found too heavy and costly for an operation which can be and is in ordinary practice carried out fairly efficiently by cheap local implements. It may be pointed out that in the methods of dry land cultivation (at least in the Mysore State) the ideas underlying the Campbell method are practically all followed, except that cropping is every year and not every other year.

12. *Cropping Every Alternate Year.*—This aspect of dry farming, *viz.*, the skipping of one crop, in other words, the interposition of a fallow year, has been emphasised in American practice. Where the rainfall is very low, say, below 15″ or 18″, it is very likely to prove a great advantage, but where the rainfall is more it is doubtful if it can be advised. As however dry farming practices proper are required only in the tracts of the former kind, it will be an advantage to interpose a fallow year between two crop years, that is to follow a crop year with a fallow year regularly. In the alternative, it may be arranged that two crops are taken in three years. In the Dry Farm Research Station in the Punjab this kind of cropping in alternate years on any field has been found to be decidedly beneficial. The same experience has been the case in the Bombay Dry Farming Stations also, so that for tracts of similar rainfall (in Panjab it was between 9″ and 16″) this alternate cropping will be an important dry farming practice.

It is however of the utmost importance that during the fallow period the field should be kept perfectly clean of weed growth, by frequent stirring of the soil, as already mentioned. The depletion of soil moisture to great depths by even a small crop of Bengalgram has been referred to already (*vide* pp. 70–71), the following additional figures obtained on the Panjab Dry Farming Research Station

will be found equally useful in this connection. Thus the moisture content on clean weeded and unweeded fallow plots was as under:—

	Moisture per cent. on oven-dry soil						
	0–6″	6–12″	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.
Weeds removed ..	3·55	7·86	12·44	13·11	12·58	10·17	8·22
Weeds standing ..	1·54	4·71	6·49	7·71	7·64	5·15	3·50

As a matter of fact the need for keeping the fallow clean of weeds cannot be too strongly emphasised. With this important precaution therefore alternate cropping as a dry farming practice can be recommended for tracts of low rainfall.

Quality of Dry Farmed Crops

The yield of crops under dryland conditions cannot of course be comparable with those obtained when they are grown under better conditions or under irrigation, but they make up by their higher content of nutritive material, *viz.,* proteids, as a compensating feature. The proteid content of grains has indeed been found to vary inversely as the moisture supplied to the crop (within practical limits). Thus in dry farming experiments in Utah, the following was observed :—

	Inches of water supplied	% Proteid content of grain
Indian corn ..	7·5	15·08
	15·0	13·48
	37·3	12·42
Oats ..	7·0	20·79
	13·2	17·29
	30·0	15·49
Wheat ..	4·6	26·2
	10·3	19·93
	21·1	16·99

A very good illustration of some aspects of dry farming is provided by the dry farmed cocoanut gardens in Mysore. In these gardens every effort is made to receive and impound as much of the rainfall as possible. This is aranged in practice firstly, by putting up bunds across the shallow valleys of the gardens and across the slopes when the gardens are formed higher up. These serve to impound and retain the flow for several days, so that the water soaks as deeply as it can into the soil. The gardens are kept in a ploughed condition with the very first rains and three ploughings are usually given in the early part of the monsoon. This puts the soil in a fit condition to absorb as much of the rainfall as possible, without allowing it to run off the surface. The same effect is also sought to be attained sometimes by forming the gardens on a kind of moderate terracing, so that the surface is level and not sloping. After the rainy season is over or towards the close of the monsoon in the months of October and November, three more ploughings are given, which produce a sufficiently thick mulch to retain the moisture

so absorbed in the soil itself or to lock it in safely. The repeated ploughings also result in an exceedingly clean and weed-free surface, as nearly every weed seed which can sprout at all comes up in these different intervals of ploughing and is promptly killed by the next ploughing. These six ploughings and the bunding up across the line of flow of the rain-water are carried out unfailingly almost like a ritual.

Another good illustration of dry farmnig principles is provided by the methods of sugarcane growing in many parts of Upper India where sugarcane is largely cultivated as a purely rain-fed crop, *i.e.*, without irrigation. The prolonged preparatory tillage and the frequent harrowings help in receiving as much of the rainfall as possible into the soil and in retaining it therein without much loss by evaporation. The rolling of the soil both before and after planting bring up the moisture close to the seed setts and helps successful germination. Frequent hoeings reduce loss by transpiration through weeds and by evaporation. Fields are also divided into square or rectangular sections by means of low bunds, so that the rain-water in the growing season is largely impounded in the field. The whole system is excellently designed for making the best use of the rainfall.

CHAPTER XVIII

SOIL EROSION AND METHODS OF CONTROL

MUCH public attention has been drawn during the last few years to the subject of soil erosion as one of the main factors in bringing about a permanent ruin of agriculture in many parts of the world, to its growing menace and to the need for protective measures which will arrest its progress, if not prevent it altogether. The erosion referred to consists in a gradual removal of soil from cultivated fields resulting in a complete denudation of the soil cover and making the land quite unfit for cultivation. Such removal or stripping off of the soil is due to the action of heavy rain and of running water, primarily, helped by many accessory circumstances; to a lesser extent strong winds and storms are also potent causes. The action of these agents in the formation and transport of soils has already been fully dealt with (*vide* chapter on Soils); we shall now deal with them in some detail from the point of view of soil erosion.

NATURE OF THE DAMAGE

(*a*) *Loss of Soil.*—The soil cap of the land surface of the globe which may be considered fit for growing crops can be reckoned only in inches or at the most including part of the raw subsoil below, in perhaps a few feet, whereas the radius of the Earth is reckoned in thousands of miles, being as a matter of fact approximately 4,000 miles. What an infinitesimal fraction the soil therefore constitutes of the earth's bulk can be thus realised. When it is remembered further that even this negligible depth of a few inches has taken centuries to develop into this condition and that it is this infinitesimal fraction which furnishes the food of mankind, it will be realised how precious the soil is. The loss of this invaluable and irreplaceable material or any reduction in its quantity should therefore cause serious concern.

Erosion does not always result in a complete denudation of the soil but consists more generally of a gradual washing out of the soil, especially the finer particles which really form the fertile fraction. This kind of removal or washing out goes on practically on all soils and regularly every year, but conditions occur which may greatly accentuate the loss. For example, on the plateau of Mysore with its highly undulating surface, erosion is very severe and whole masses of excellent soil many feet in depth may be washed away, exposing unweathered whitish raw soil, decayed rock, or the unaltered parent bed rock itself, underlying this great depth of soil.

(*b*) *Cutting up of Surface.*—The loss of the soil is not the only kind of damage which results from these causes. Equally serious is the cutting up of the surface by gullies or scours, through which the water finds its way carrying the soil with it. Such gullies

Typical Soil Erosion in Mysore. The left half is very deep red soil, facing the gully in front from which a similar depth of good soil has been removed by erosion. *Photo by Author*

may be few or many, shallow or deep, wide or narrow. In extreme cases a veritable maze of miniature canyon-like gorges or cuts may be carved on the land surface—a feature which can be seen in some badly eroded regions of Upper India. Even in a very minor degree when only a few scours may be formed the surface becomes too seriously cut up to be put under cultivation. The erosion and gully formation usually go on at a steadily accelerated rate, each year's scour being deepened and widened by the next year's erosion at an alarming rate.

(*c*) *Flood Damage.*—The uncontrolled rush of water which is generally the cause of bad erosions often results in the years of heavy rainfal to a serious flooding of the country, to destruction of property, to the silting up of valuable fields and the washing away of the top soil from other fields. The causes of soil erosion therefore bring in their train these additional factors destructive to agriculture.

Steady erosion of the soil also takes place along the coarse of such rivers and the banks of these rivers get eaten into and become merged in this river bottom, on the outer side of the bend in the course of the river, so that both during floods and during normal flows, there is considerable erosion going on on both banks in the former case and on one bank in the latter case. If fields adjoin such river banks, some kind of protection has to be provided, in order to mitigate the effect. This usually takes the form of planting up the sides with trees like willows or plants like the wild sugarcane, giant grasses and the like, or by means of plaited twigs and so on. In special cases elaborate rivetment will have to be put up, especially when dwellings are located near the banks and are threatened with damage.

Causes of Soil Erosion

The causes which give rise to soil erosion are (1) uncontrolled flowing water, which is greatly increased by others; *viz.,* (2) the slope of the land; (3) the extent and distribution of the rainfall; (4) the nature of the soil; (5) the nature and extent of vegetation on the land; (6) the manner of ploughing the land; (7) the kind of farming adopted; and (8) the nature and efficiency of the control methods.

1. *Running Water.*—The action of running water has already been explained. Erosion begins whenever there happens to be any slight depression of or subsidence in the ground however small it may be, along which water begins to flow in a little rill and to erode and widen it eventually into a large scour. Erosion may start sometimes along pathways, or country tracks, made by pedestrians or sheep or cattle which usually have a settled track. It may start often along ruts made by carts, this being a very prolific source of injury, even on comparatively level ground. The point is that if there is nothing done to control the erosion (by methods to be described presently) every year the erosion increases with accelerated speed and becomes a gaping gully. The smaller ones join a larger one

these join together lower down still larger ones, which may finally meet the rivulets, tributaries and the larger rivers which drain the country and carry with them at the same time the load of soil obtained from these many-branched streams and streamlets.

2. *The Slope of the Land.*—The force of the running water increases as the slope of the country increases, the more hilly or undulating the surface the greater is the chance for erosion. In the plateaus, the foothills, hillsides and the upper reaches of the rivers the flow is more rapid and the erosion likely therefore to be more serious. Erosion may completely cease on the dull flats and the deltas where the rivers flow sluggishly along, giving rise to meanderings rather than erosion or gully formation. The danger in such regions is the silting up of lands during abnormal floods.

3. *Rainfall.*—The chance for erosion is greater where the rainfall is not only heavy but also comes in a great and sudden downpour concentrated in a short time rather than in light showers distributed over a longer period of time. In the latter case there is time available for the rain-water to sink into the soil as deep as it can penetrate, while in the former case, the fall is too great and sudden to be absorbed by the soil and the water finds its way out only by surface flow, creating scours wherever it can.

4. *The Nature of the Soil.*—Erosion is also influenced by the nature of the soil in the tract. On coarse sandy, gravelly or stony soils, the erosion is less than on the finer loamy or clayey soils with no admixture of such coarse material. The coarse particles and stones act more or less as hindrances to the rapid flow of water and may be almost said to exercise some amount of control. It is really on the better class of soils where one could least afford to lose the soil that erosion is more than in other types. On the red lateritic soils, although the surface may be dry and hard, and there is no loose soil to be washed down, still once an erosion begins along a path or rut it can proceed rapidly and assume serious proportions; the deeper the soil moreover the more serious the erosion until the gullies reach the bed rock. On the black cotton soils the erosion is usually what is called 'sheet' erosion, the soil on the whole field being gradually carried down the slope rather than the formation of narrow gullies. Even on the almost level tracts of these soils where the slope is hardly worth mentioning, much erosion of soil by this kind of erosion takes place.

5. *Vegetation on the Land.*—Where forests have been denuded and tree growth extinguished on hill slopes, the door is opened to much greater erosion than otherwise. Similarly where pastures with soil binding grasses are not allowed to grow but are freely grazed down indiscriminately before they are hardly up by herds of hungry cattle and sheep the soil loses its protective cover and becomes open to erosion.

6. *Method of Ploughing.*—In the case of hillside farms when the fields are ploughed up and down and not across the slope

conditions become favourable for erosion, as each up and down furrow is practically a little opening for the water to flow down and create a gully eventually. The loose ploughed soil is in a condition that can be easily moved down by flowing water during a heavy burst of rain. The ploughing across the slope on the other hand checks the flow at every furrow and effectively controls the tendency to erode.

It must be noted furthermore that the stirring and loosening of the soil which results from and which is indeed the object of all kinds of ploughing is highly favourable to erosion, wherever the causes leading to erosion operate. The silting up of many tanks is the result of such ploughing of lands situated higher up above the tanks, especially when there has been neglect of other kinds also. The ploughing up of the dry beds of tanks either entirely or on the outer margins for cultivation in emergencies has also a similar effect, and can be justified only as a relief measure against distress. It is also seriously feared that the ploughing up and cultivation of all waste lands, especially those lying on the higher levels in the catchment areas of tanks which is now going on rapidly as the result of the "Grow More Food" campaign will accentuate the erosion of these areas and the silting up of the tanks. The need is therefore all the greater for the adoption of not only the traditional measures like the deepening of tanks and the annual removal and carting of silt to the fields, but also for other effective methods of erosion control described below. The evil of such erosion and the deterioration of tanks by silt accumulation in such situations being thus more or less unavoidable all efforts should be directed towards checking and reducing it to the minimum possible.

7. *Kind of Farming.*—If the kind of farming consists in raising single crops on a large scale and that as an annual crop, requiring ploughing, seeding and cultivating every year it tends to increase the liability of the soil for removal by erosion. A mixing together of a few fields of permanent or semi-permanent crops even of grass very much reduces this tendency to erosion.

An extreme instance of serious erosion and denudation of soil is furnished by the hill slopes in the Nilgiris, where due to the extensive cultivation of potatoes every year and the necessary tillage operations, the surface has become exceedingly vulnerable to the forces of erosinn, which is now reported to have assumed alarming proportions.

8. *Lack of Control.*—The most important is of course the nature and extent of the control measures adopted. The control is of course to prevent the unchecked flow of running water over the fields. If no control methods are taken or if they are poor and not adequate to the needs, erosion becomes very serious; the extent of erosion will in fact be in direct proportion to the quality of

the control exercised, abnormal times and calamitous erosions being in the nature of acts of God.

Extent of Erosion

The extent of erosion, that is to say, the quantity of the soil removed by erosion by surface run-off of rain, has been estimated variously and determinations have been made both under field conditions and in laboratory experiments (imitating field conditions). In Indian experiments (at Dacca) the amount has been found to vary from 20 tons to 170 tons of soil per acre, carrying with it in the shape of fertility 74 lb. to 3,094 lb. of total nitrogen, 2·3 lb. to 26·7 lb. of available P_2O_5 from each acre approximately. In these experiments even on the same slope the erosion varied with the nature of the soil, the variation being from 1½ to 3 times as between one soil and another (A. F. Sen, *Ind. Jour. Agr.*, June 1946).

In the Bombay Dry Farming experiments on a 3% slope and a clay loam soil, the erosion was found to be 40 tons of soil per acre. American figures show that on a slope of 3·6% the erosion was 41 tons of soil per acre on soils ploughed 4″ deep (Missouri) and on a slope of 2% it was 40 tons, and in another case (N. Carolina) it amounted to 25 tons per acre.

The following table gives a further idea of the extent of erosion under different conditions of cropping and of the great saving by certain methods, both in respect of the rainfall and of the quantity of soil lost :—

Results of 14 Years

Tillage and cropping systems		Average yearly loss: Rainfall per cent.	Average yearly loss: Soil tons per acre
Fallow and ploughed 8″	..	**30·3**	**41·1**
Continuous corn	..	**29·4**	**19·7**
Continuous wheat	..	**23·3**	**10·1**
Corn, wheat, clover in rotation	..	**13·8**	**2·8**
Continuous blue grass	..	**12·0**	**0·3**

—*Missouri Agl. Expt. St. Bulletin* **177**

Methods of Erosion Control

1. *Breaking the Force of Flowing Water.*—The most important method is the breaking of the force of the flowing water, by various kinds of impediments or obstructions across its track. These may take many forms such as (*a*) in a small way the planting or pitching of stone slabs across the scour, a little wider than the scour so as to save the sides also; the flow is thereby arrested and the water has to stand until enough accumulates to overflow the obstruction; (*b*) when the scour or gully is wider, putting up dam-like stone built embankments, provided with an overflow weir, so that the water is stopped and kept back until it gains enough volume to overflow; (*c*) as the gully or valley widens further, longer

and higher embankments or regular dams behind which the water collects in the form of a tank or lake, from which water can be drawn and utilised for irrigation, if the banks are not too steep. Large lakes and reservoirs are formed when the water to be controlled assumes the form of rivers or rivulets. This kind of obstruction of flowing water amounts to a mere "gully plugging" in the case of the narrow and steep gullies, to the formation of small tanks or *kattes* for affording water to cattle and further down widens into lakes or tanks, large or small, when they become sources of irrigation, and control and utilisation are both combined in one method. If any large stream is followed up its course along the valley line the branching and rebranching into innumerable little streamlets, scours and gullies, it will be seen what a great amount of damming up of this kind is necessary and possible.

It must however be remembered that damming up of this kind will interfere with the water flowing into tanks lower down which may be objected to, and where large schemes are attempted, regular riparian rights not only to water but also to the silt it brings down may be infringed and may even lead to litigation by the people affected. As a matter of fact it has been pointed out that a system of damming up all erosions, many of which are at present 'feeder channels' to tanks, will reduce the quantity of water received by these tanks and therefore impair their usefulness and capacity. On the other hand the rate of silting up of tanks which though slow is still a source of impairment to such tanks, is reduced; but this advantage is too small and too remote to balance against a reduction of the income of water to the tanks. In any case this kind of control of flowing water is the most important method of combating erosion.

2. *Reduction of the Slope of the Land.*—This is one of the obvious methods of control and has been adopted from the earliest times. The method consists in making the cultivated area as level as possible. An extreme form is the construction of terraces for rice cultivation, where erosion is completely prevented, as the water has to stand in the beds several inches deep, a feature peculiar to rice cultivation. This kind of terracing into small beds is very difficult, laborious and expensive; nevertheless whole hillsides may be seen carved out in this manner in nearly all rice-growing countries.

In ordinary dryland cultivation such terracing need not of course be attempted but some moderate terracing is required. Strips, wide or narrow, depending upon the depth of soil, have to be made across the slopes and along the contour lines and the lower margins of such strips have to be provided with low bunds, so as to further prevent surface wash. Field margins in Mysore are generally made much wider than necessary even up to 6′ or 8′ and these strips are grass covered, affording a little grazing, but they serve in addition to bind the soil and prevent the wash. In fact

many soil binding grasses are utilised for this purpose even under other circumstances.

3. *Cross Drains.*—Sometimes drains may be cut across the slopes along the different contours, the lower rims of the drains being elevated into low dams in addition. These contour drains are very effective in preventing surface wash on fields or estates situated on hill slopes. The water has to flow into the drains, remain there till they are full or come to overflow level and then flow out. Very often the rainfall may not be heavy enough for such overflow and so scouring and surface wash are effectively prevented

It must be borne in mind that surplus water *will have* to be led out; one's skill comes in, in leading or diverting it in such a manner that damage to cultivated land is thereby prevented. The principle is, to prevent the flow altogether, if possible, and/or to protect the field in any case. Both cross and contour drains suitably aligned will largely secure this end.

4. *Tree Planting and Afforestation.*—Many eroded regions have been the result of the denudation of tree growth on them. Reforestation and the creation of a good tree cover are means of reclaiming such land and of preventing erosion on other open waste lands. Though the departments of Forestry adopt systematic measures for the conservation of forests, other interests like charcoal production, wood pulp for paper-making and such industrial requirements may prevail and lead to a denudation too wide and rapid to be overtaken by plans of afforestation. Suitable systems of restricted felling, natural regeneration and planting of quick-growing trees will have to be adopted to prevent permanent damage. An extension of tree planting by some system of village forests may save much erosion on the countryside, besides serving other useful purposes.

5. *Regulation of Grazing.*—Closely allied to these measures is the regulation of grazing on hillsides. If the grazing is open and uncontrolled the grass is grazed down as soon as it is up and before it has had time to establish a good root system, which if well developed may bind the soil. A 'close' season will have to be observed for this purpose and grazing permitted only on a system of rotational grazing, the area being suitably divided into blocks for this purpose. Both from the point of view of abundant grazing and of the protection from erosion, a rational and well-controlled system of grazing is essential.

6. *Strip Cropping.*—Instead of growing a single crop over the whole area of the farm in one block both up and down the slope, it is preferable that more crops should be grown in alternate strips across the slope, the rough terracing according to the contour being taken advantage of for the purpose. This system of strip cropping should include a belt of deep-rooted leguminous crop or a semi-permanent fodder crop and soil-binding grain crops which should alternate with ordinary field crops like cotton, maize, gingelly and so on. The method is calculated to arrest surface flow, not only

in the crop season when the crops are growing but also after the grain or other crop is harvested, when the semi-permanent fodder crop will remain on the land and check any free flow of surface water.

The extent of the prevention of erosion effected by strip cropping may be realised from the following figures quoted by Sir W. J. Jenkins :—

Loss of soil from strip cropped fields	2·7 tons per acre in one year	14·5 tons per acre in another
Loss of soil by ordinary cropping methods	104·6 tons per acre in one year	64 tons per acre in another

Soil Erosion and Other Damage by the Wind

The action of the wind in causing damage is two-fold, *viz.*, (1) the actual removal of the soil, and (2) the deposition of sand on cultivated land. The action of high winds, tornadoes and whirlwinds has already been referred to (pp. 28–29). Where the region is subject to regular visitations of storms of this kind it will be almost impossible to control this agency. The region called the "dust bowl" in the U.S.A. has been reported to have been reclaimed after the advent of irrigation in that tract. The reason is that it has become possible to provide a cover of various grasses, legumes and other crops over the soil, which have proved an effective barrier against the soil-stripping action of the winds.

The deposition of sand on cultivated land happens usually in the neighbourhood of sand dunes or other tract of blowing sand, from which sand is easily blown on to good cultivated land. The only method by which this can be prevented consists likewise in establishing some soil or sand-binding vegetation on these dunes. Suitable grasses, generally with a creeping habit, and trees which can grow in sandy situations have to be planted and their growth encouraged and the drifting of the sand prevented thereby. The cashewnut tree and the screw pine (*Pandanus odorotissimus*) are common trees for this purpose, while among grasses there is a large variety of perennial kinds suitable. In the following list are given the names of a large number of plants, grasses, shrubs, creepers and trees, which have been found useful for this purpose :—

Sand-Binding Plants

In India—

Acacia arabica Willd.
A. eburnea Willd.
A. Jacquemontii Benth.
Agave americana Linn.
Agrostis alba Linn.
Alhagi maurorum Desv.
Andropogon foveolatus Del.
A. laniger Desf.
Aristida depressa Retz.
A. setacea Retz.
Atriplex nummularia Lindley.
Calotropis gigantea R.Br.
C. procera R.Br.
Canavalia obtusifolia DC.
Capparis asphylla Roth.
C. spinosa Linn.

Casuarina equisetifolia Forst.
Cenchrus catharticus Del.
C. montanus Nees.
Eleusine aegyptica Pers.
E. flagellifera Nees.
Eleusine scindica Dutnie.
Elionurus thirsutus Munro.
Hydrophylax matima Linn.
Indigofera sp.
Ipomæa biloba Forsk.
Jatropha Curcas Linn.
J. glandulifera Roxb.
Launæ pinnatifida Cess.
Melanocenchris Royleana Nees.
Opuntia Dillenii Haw.
Pandanus odoratissimus Willd.
Pennisetum cenchroides Rich.
Perotis latifolia Ait.
Pupalia orbiculata Wight.
Saccharum ciliare Anders.
Salvadora oleides Dcne.
S. persica Linn.
Spinifex squarrosus Linn.
Sporobolus orientalis Kunth.
Tamarisk gallica Linn.
Zizyphus nymmularia W. & A.

—(From the *Dictionary of Economic Products of India,* by George Watt.

In Europe and America—
Ammophila arenaria
A. breviliguleta
Agropyron repens
Calamovilfa longifolia
Elymus spp.
Redfieldia flexuosa

(From the *Manual of the Grasses of the U.S.A.,* by A. S. Hitchock.)

In the sand dunes of Talakad in Mysore the method saved the town from invasion by sand, which at one time threatened to cover it up in the same way as it had buried under it the ancient temples and other structures near the town. Belts of trees planted across the usual direction of the wind which therefore act as wind breaks can also help, but the binding of the sand arrests the trouble at the very source and is therefore more effective.

CHAPTER XIX

THE PROTECTION OF CROPS AND CONTROL OF PESTS AND DISEASES

ONE of the serious obstacles to normal crop production is the damage caused or likely to be caused to crops by various agencies, which often neutralise the favourable effect of many of the factors of crop production and which may sometimes result in even total destruction of crops. Crops therefore need adequate protection from these destructive agencies. These agencies comprise (1) natural forces or acts of God which cannot be foreseen and which cause vast damage over very wide areas, like floods, storms and cyclones, etc.; (2) inroads by animals of various kinds; (3) pests and diseases.

NATURAL DESTRUCTIVE FORCES

In the case of visitations like storms and floods it is very difficult to take protective measures, as these cannot be foreseen. Still, if the regions or the fields are known to lie along the tracts of high winds, storms and cyclones or if they lie along the banks of rivers or other situations which are likely to be flooded in abnormal years, then it will be well to have some permanent protective measures, which will be in the nature of an insurance, being directly useful when a visitation does take place but normally remaining unnecessary. Shelter belts or wind breaks composed of suitable trees planted across the direction of the usual high winds as in plantations, props or upright standards for supporting sugarcane, plantains and similar crops against storms and cyclones, and substantial flood banks of suitable height for keeping out the flood water from rivers in spate are instances of the kind of protection against these natural agencies. Frosts occur in certain tracts and cause sudden and extensive damage to crops and suitable protective measures are likewise necessary, to which reference has already been made (*vide* Chapter I).

INROADS BY ANIMALS

Stray cattle constitute the commonest cause of damage everywhere and wild animals, both large and small (like jackals, wild pigs, monkeys, porcupine, deer and even elephants) in regions where forests may not be far off. The genus *homo* is not to be neglected and may sometimes prove more destructive than any other agency. Gardens of permanent or semi-permanent crops must invariably be strongly protected while in the case of the ordinary field crops protection will have to be provided according to circumstances, such as, for example, where a crop may occupy the land when all the surrounding fields have been harvested and are

open to free grazing by the village cattle. Fields of sugarcane and gardens of plantains, betel vines, etc., are crops of this kind which may be grown in the midst of large stretches of rice land. Where the fields are commanded by wells and crops can be grown all the year round, the fields have to be invariably fenced and protected.

Protection takes the form usually of fences of various kinds and sometimes of low walls. Special situations may require deep trenches and embankments to keep out elephants, in regions where wild elephants are found. For valuable trees, trees guards of various kinds may be put on like a girdle up to a man's height, or poison baits may be laid or traps set up and so on, but these are special measures applicable to special cases.

Fences

Fences may be of many kinds, but all of them should conform to the condition that they should serve as efficient barriers against intrusion. They should be strong, high enough, should have no gaps, and should be as permanent as possible and kept in thorough repair always. It requires a very strong fence indeed to keep out a hungry cow or buffalo from a field of green crop. Fences may be either 'quick', *i.e.*, be composed of living plants or 'dead', *i.e.*, composed of any other material like wood, stone, earth, metallic wire or wire-netting.

(*a*) *"Quick" Hedges.*—Quick hedges should be composed of plants suitable for the purpose, that is to say, they should be (1) not edible for cattle, sheep or goats; (2) capable of withstanding heavy pruning; (3) have a much branching and bushy habit of growth, right from the base upwards, so that no gaps will be left below, as the stem grows up; (4) preferably with abundant thorns sufficient to keep away both men and animals; (5) capable of quick and easy propagation preferably from cuttings. In effect, they should form an impenetrable thick barrier and be capable of being maintained in that condition.

"Quick" Hedge Plants.—There are many kinds of plants answering more or less to this description which are in general use for planting as quick hedges. The following are some among these :—

1. *Balsamodendron berryi,* Arn.—This makes a very thick impenetrable thorny hedge; it should be cut back occasionally to induce bottom branching.

2. *Euphorbia tirucalli,* Linn. is a very common hedge, very easy of propagation, but leaves gaps below as it grows up which will have to be filled in with fresh planting and thorns.

3. *Synadenium grantii* is an excellent hedge, forms an impenetrable wall-like screen; it is one of the best for quick hedges and can be hardly surpassed for this purpose.

4. *Agave Americana,* Linn. ('Railway aloe') is a serviceable hedge and will keep efficient for many years, until individual plants

pole and die off, when the gap will have to be filled by new planting. The planting will have to be done on a mound and for the first two years till the aloes grow the protection will be mainly from the mound and adjoining trench. The hedge is also useful as it yields some fibre for ropes for farm use.

5. *Prickly Pear* (*Opuntia dillenii,* Haw.) furnishes one of the most efficient of quick hedges; it is very easy of propagation and makes an impenetrable thorny hedge which will keep out both men and beasts, effectively. It is however fast disappearing, if not gone altogether, having been destroyed by the cochineal insect which was introduced purposely to this end. As a hedge plant and under severe control it deserves to be kept on.

6. *Acacia arabica,* Willd, will form a very thorny and effective hedge, whether quick or dead, as it is very thorny and strong. It is however slow to raise and will have to be cut back in such a way that the branch is cut only half-way through and is bent down so as to cover gaps.

7. *Pithecolobium dulce,* Benth, an excellent and very strong hedge; the stems are stout and bear strong short spines; the tree coppices freely and when cut low down, grows into a strong bush with a strong stout main stem and branches almost equal in size, furnishing both uprights and cross poles of very great strength. Stout branches should be cut slantingly and bent and laid down across the hedge to further strengthen it. The only drawback is that it is eaten greedily by cattle, sheep and goats and has therefore to be carefully tended, especially in the earlier stages.

8. *Thevetia neriifolia,* Juss. makes an excellent screen, both evergreen and ornamental; but leaves gaps below when it grows up, which have to be filled with fresh planting or thorns.

9. *Lawsonia alba,* Lamk. 'privet' also makes a good hedge and can be kept pruned and trimmed into a neat wall-like bush. It is not eaten by cattle.

10. *Clerodendron inerme,* Gærtn., is another equally good hedge which can be treated in the same way as the privet. It is also not touched by cattle. It lacks strength and can be easily broken through.

11. *Palmyra* (*Borassus flabelliformis,* Linn.).—This comes in a special class, as it is a tree of varied uses and is largely planted in groves in certain parts of the country notably the southern districts of Madras and the Northern Circars. It is raised from seed and will have to be planted closely. After the plants come up and for about ten years thereafter it will prove a thick, strong impenetrable hedge. Later on it ceases to be a hedge.

12. *Wild Date* (*Phœnix sylvestris,* Roxb.) belongs to the same class as the above and has to be treated in the same way.

13. *Lantana indica,* Roxb. is easily propagated, quickly established and fairly effective especially after a couple of years, when the spines harden and the plants become bushy. It lacks strength

but affords moderately good protection. In recent years it is subject to the attacks of a mealy bug which puts back growth and makes it less effective. It encroaches on waste land and open jungles and soon overruns them, which thereafter cease to afford any grazing. It has to be cut frequently and kept under control.

14. *Carissa carandus,* Linn. is a highly thorny hedge, growing into an impenetrable bush; it has to be cut low now and then to prevent it from straggling and taking up too much space It yields an edible fruit.

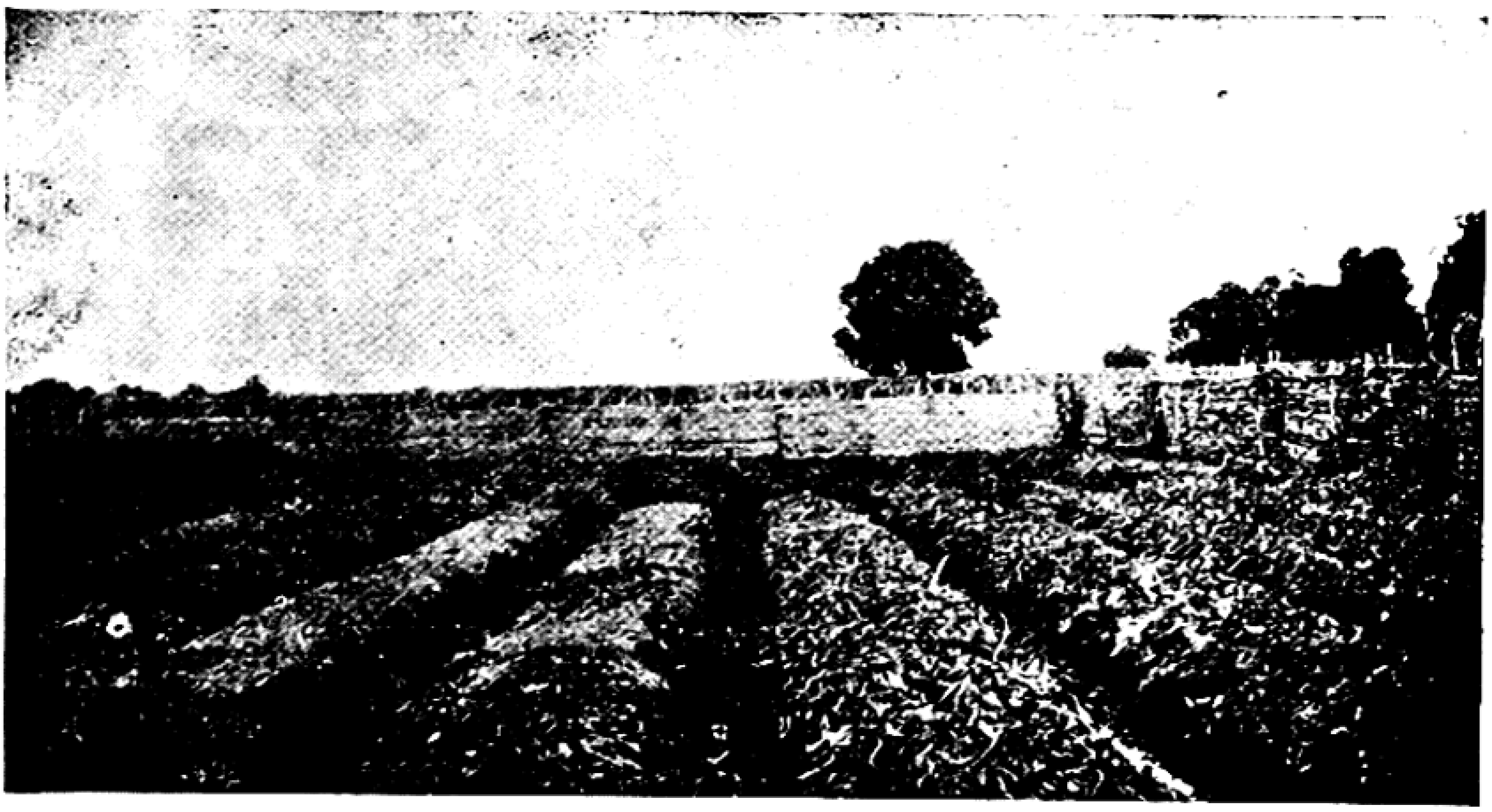
Other Forms of Fencing.—Fencing is frequently made of what may be called "dead" wood, as distinguished from the "quick" hedges considered so far. This is intended for comparatively temporary periods of one or more crop seasons, as a general rule. As a crude fence it may be made up of only a line of thorny branches stuck closely along the ground and kept well patched up when necessary. In a rather elaborate form it may be made up of close woven mats of willowy twigs of the lantana, or *Dodonia viscosa* which are prepared in sections of about 4′ in height and 10′ or 12′ long and erected all around the field, with strong uprights at suitable distances to support the fence. A much stronger fencing of the same type is made out of bamboos, either whole or split along the length and plaited together like a mat or fixed all around the field like a wall. Bamboos are largely made use of in more than one way as fencing material.

Poles of the *Sesbania grandiflora,* fronds of cocoanut trees, and of the wild date and many other materials according to the ease of procurement are used for fencing in this way. Some of them can, with ordinary repair, serve for two or three years, while others perish within a crop season or year.

Very often a combination of 'quick' and 'dead' hedge is made; *Erythrina indica* is grown or green wood poles planted which easily strike root as uprights close together, and across these standards 'dead' wood cross poles of bamboo, *Sesbania,* cocoanut and date fronds are tied, forming a fairly good protection which often lasts years.

Very strong and permanent wooden fencing is not unusual in farms; they are made of strong sound uprights and railings across, all of good sawn timber, cut and fashioned to suitable lengths and put up securely so as to last for many years. Such fences do not occupy the same amount of ground as the quick or thorny hedges do, they do not harbour vermin, there are no roots (as in the case of the quick hedge plants) to interfere with the crop, which can therefore be grown very close to the fence, and there is a general air of cleanliness about them, as against most other forms of fencing. Of course such fences are very costly and can be thought of only in special cases.

Wire Fencing.—The most popular form of fencing, though costly, is wire fencing, made up either of barbed wire or ordinary



Pig proof bamboo fence, strongly plaited and almost wall-like usual in sugarcane fields, Shimoga District, Mysore. Views of field after harvest of the sugarcane showing the fence intact. *Photo by Author*

smooth wire rope. In addition to the cost of the wire, there is the cost of the uprights to be considered which are stone pillars with holes in them to pass the wire through and of the strong corner posts and struts. Where stone cannot be had, strong wooden posts have to be put up, but these are unsatisfactory as they are subject to rots and white-ant damage and are liable to break; all this leads to sagging and gaps in the fence. Cement concrete posts, reinforced or plain, with staples set in suitably for passing the fencing wire through are also coming into use; they have the advantage that they can be easily made in any shape or dimension. At least five or even six lines of wire will be needed on each pillar, placed about 9" (the bottom two lines however placed 6" apart) one above the other and good care will have to be taken that the wires are stretched taut and also kept in that condition. Very often wire-fencing is supplemented by some kind of quick hedge which fills gaps and acts also as a screen.

Wire-Netting, Woven Wire-Fencing, etc.—Other expensive fencing is also used where the value of the crop or other circumstances will justify the expense. Such are woven wire fencing (called Excelsior or 'pig-proof'), wire-netting of different mesh and even electrified fencing. In the case of the first two it will be necessary in this country to secure the bottom line very strongly to the ground by pegging it down at frequent intervals, because it has been the experience of those who have used these that wild pigs are able otherwise to thrust their snouts below the netting or woven fencing and to lift it up sufficiently to creep through.

Electrified Fencing.—A recent development is the use of fencing which can be electrified so as to give a mild but sufficiently deterrent shock to animals coming in contact with the wire, which afterwards learn to keep away from and avoid the wire. Electrified fencing is said to have become universal in Danish farms and to be in use on many farms in the U.S.A.

The object on those farms is however to keep the owners' cattle from straying outside or into the neighbour's field but of course it serves equally well to keep outside cattle from trying to get inside such fencing. In Indian villages, all fencing is a most unpopular institution and an electric fencing is not particularly calculated to pacify the irate villager.

WALLS

Sometimes walls are erected instead of fences, which serve the same purpose but more effectively. Walls for farms or fields may be constructed merely of mud or may be made up of stones piled up in the shape of a wall or occasionally built up with brick and mortar in the usual way.

Walls are put up as enclosures generally in the case of self-contained farms, with the owner and his family residing in them. In the case of mud walls, the kind of the earth or soil should be

suitable for the purpose, in its physical consistency. They are built in three or four courses of about a foot or two in height at a time, at intervals which allow of the material drying slightly and setting. With suitable earth even a height of 6′ is possible. Mud walls are generally provided with a coping of tiles or other material as a protection from rain.

Stone walls are common in fields in regions where the surface is strewn very thick with stones, near quarries or where stones are very easy and cheap to get. As a matter of fact the putting up of a stone wall is looked upon as one way ridding the field of stones, so that it really serves a double purpose. Stony soils, hillside fields in the trap rock country, fields in the regions where "flag" stones like "Cuddapah slabs" or "Shahabad stone" are quarried and odd sizes and rejections are available in plenty, are the places where walls of these materials are common. These walls are built up by merely piling up the stones or slabs in the shape of a wall and are without any mortar or wet earth to bind them; they are sometimes referred to as "dry" walls. They are however put together with such skill that they are firm and substantial enough, despite the lack of this binding material. In some parts of Mysore, large granite slabs about 6′ or 7 in length, about 2 broad and 3″ in thickness are planted vertically close to each other and serve as a wall; many gardens can be seen enclosed in this manner. The schistose formation of the granite in the State is favourable for the quarrying of such large slabs.

On hillside farms and fields these structures or field walls of stone serve the additional purpose of preventing surface wash or erosion.

Other Forms of Protection against Animals

Other forms of crop protection against animal damage have also to be resorted to, both because fences are not always as efficient as they should be and there are destructive animals like monkeys and birds which fences cannot keep out. A close watch has to be kept both day and night to scare them away or to shoot and kill them where possible. Birds descend down in great swarms especially in the mornings and evenings, when one has to be specially watchful. It is to be remembered that some animals like monkeys, parrots, etc., are forbidden to be shot in India and have therefore only to be scared away or trapped and transported to the jungle as in the case of monkeys.

Fruit trees will generally have to be protected from thieves, rats, squirrels, flying foxes, etc. Special methods like tree guards, nets, cleaning out of tree tops and chasing down rats and squirrels, etc., which may be appropriate to each case, will have to be adopted. A good watchman in the garden or field with a gun to fire an occasional blank shot or to explode a small explosive charge in the night can do much to keep out intruders, whether men or animals. Field

rats and crabs do a lot of damage in rice fields. Rat catching "wodders" are experts in locating and catching rats and are sometimes employed for ridding the field from this pest. Rats can be also gassed or smoked out in their burrows with special smoke pumps. Crabs are often caught in pot traps, using bran as a bait.

CROP PROTECTION AGAINST PESTS AND DISEASES

Grops are attacked and damaged by innumerable insect pests and fungus and other diseases and a most important form of crop protection is to prevent or combat and keep them down, so as to save the crop entirely or to minimise losses as much as possible. There is hardly a single crop which is not subject to these attacks. Crops are also attacked in all stages and nearly every part of the crop, roots, stems, leaves, flowers and fruits, and produce while on the crop or harvested and in storage, are subject to attacks and serious damage. Roots may rot or be cut or bored through, so may the stems; leaves may shed, be eaten off or the sap sucked off, flowers and fruits both young and ripe may be eaten off, may shed, be bored through or stained, or whole plants may be killed out in all stages, even when fully grown, by wilts, rusts and blights. It is beyond the scope of this book to deal with the individual crops or their diseases and pests and reference should be made to text-books on Entomology and Mycology and in regard to individual crops to the author's *Field Crops of India*, in which the common diseases and pests of the crops and their treatment as far is known are described under the respective crops. We shall here deal only with some of the general principles of such protection.

PREVENTIVE MEASURES

Just as in the case of other diseases, as much attention has to be paid to the preventive aspect as to the remedial aspect of the measures of control. The preventive measures consist mainly in (1) keeping out infection; (2) maintaining cleanliness or plant sanitation in the farm; (3) proper attention to certain particular methods of cultivation.

1. *Keeping out Infection.*—Infection may be brought in along with the planting material, whether seeds, cuttings, tubers or bulbs, or produce that may be imported from foreign countries and States, and in these cases the governments of the importing countries have either to prohibit such imports or to subject the material to disinfection by appropriate methods before allowing entry into the country. Most countries have some kind of laws to enforce such precaution. At some ports of entry arrangements exist for fumigating seeds and planting material with hydrocyanic acid; in other cases a certificate of freedom from disease or of previous disinfection is required from the country of origin and in certain other cases the import is prohibited altogether, the ban on the import of raw coffee from the East Indies into India being an instance. These measures may leave much to be desired in their method of application and in any case when

immense quantities of foodgrains have to be imported as a measure of relieving urgent food shortage or in the case of imports over land routes and even by air, such measures become difficult to carry out and the country is open to that extent to infection from foreign sources. Anyhow this is a sphere of Government responsibility and the ordinary agriculturist is helpless in the matter.

Growers can themselves prevent infection by exercising care in the selection of the seeds or planting material they use. No seed should be sown if the grower has reason to believe that it has come from a diseased area, whether it be the grower's own field or brought from outside. Where seeds show outward signs or marks of pests or diseases, such as weevil or borers, or the red rot of sugarcane, the ring disease of potatoes and the like, such seeds should be strictly avoided.

2. *Cleanliness.*—Infection can be avoided in some cases by strict attention to cleanliness on the farm, by cutting down weed growth and scrub vegetation and wild grasses, etc., from which diseases and pests are likely to spread. Even personal cleanliness is called for in certain cases as diseases, like the mosaic of tobacco, are highly infectious and can be carried on the clothes and persons of the coolies working in the field. Betel-leaf gardens are kept scrupulously clean and entry may be refused to persons wearing shoes —which, though it appears an absurdly extreme precaution, still shows what great importance is attached by these garden owners to cleanliness.

3. *Suitable Agricultural Practices.*—Many well-recognised agricultural practices secure a considerable measure of freedom from the incidence of pests and diseases and should be adopted in the cases concerned; examples are the ploughing of fields in the autumn which brings up the grubs and pupæ of insects to the surface where they are promptly eaten by birds, the burning of stubble which destroys borers and scale insects on the stems, the transplanting of rice in preference to broadcasting which prevents the appearance of certain fungus diseases, and the general rotation of crops which prevents the carry-over or perpetuation of particular pests and diseases from year to year. Freedom is sometimes secured by the grafting of the susceptible variety on to an immune root stock, a method which saved the grape vine industry of France from the phylloxera pest.

4. *The Importance of Sowing in the Correct Season.*—It is also necessary that crops should be sown at the recognised seasons, peculiar to the localities and not planted or sown at any time, because one has ample facility for irrigation. It will be well to be guided by local custom in the matter, as that is the result of many years of experience. Sown or planted out of season, crops may be attacked by pests and diseases in some apparently unaccountable manner.

5. *Immune Varieties.*—Sowing or planting should be preferably of varieties of strains of the crop which have proved to be immune to particular diseases or pests, unless they are otherwise un-

suitable. In fact, in many cases this is the only way in which the trouble can be avoided.

Remedial Measures

Even with the best of efforts it is not always possible to keep out pests and diseases, and recourse must be had to remedial or control measures. Remedies which will be effective and at the same time practicable and cheap are not always available, although it is towards this very end that all research in entomology and mycology all over the world is directed all the time. Such as they are, it is of the utmost importance that growers of particular crops should be conversant with the remedial measures that may be recommended for the particular diseases, or pests to which that crop may be subject. They should also provide themselves with the required appliances and materials and carry out the operations promptly and thoroughly in the manner recommended. The requisite appliances like sprayers, dusters, spray preparing vats, etc., should all be put in as regular items in the equipment of the farm. This arduous task will have to be performed, for there is no *mantram* or magic wand which can ward off the pest or disease and the expense and trouble will both have to be borne.

The remedial measures consist mainly in the spraying of materials on the standing crop, which will kill the pest by acting as (*a*) a stomach poison, or (*b*) as a contact poison. The former coats thinly the leaves and other parts of the plant sprayed with the poison which the insects eat along with the leaf or other part and are killed. The latter kills the pest by mere contact with their soft bodies or shutting off their breathing pores and killing them thereby. The poisons may be in the form of dusts instead of liquid sprays, and appliances for dusting will have to be employed for this purpose.

It is not all pests that can be reached by such sprays and dusts and in these cases other methods will have to be employed; examples are cases where the damage is by borers inside the stem or roots, or leaf-miners which feed under the thin epithelial covering of the leaf surface. In many cases poison sprays and dusts may not be admissible, on account of the danger to men and animals who may eat the sprayed leaf or fruit. In these and similar cases other methods which are purely agronomic, biological or purely mechanical may be found effective and simpler. Light traps may be used to attract and kill moths; hand nets may be used and moths caught and destroyed; sticky pastes may be used to prevent insects crawling up tree trunks, or for catching and destroying with material somewhat similar to the "catch-em-alive" fly paper; crows and other birds may be attracted to the field or crop in order to feed on the grubs; tar-distrillates and other paints may be used for smearing on barks and kill boring grubs; grasshoppers may be caught in large bags drawn over the fields; poison baits may be employed; trash traps can be set up to attract moths and beetles; grubs and beetles may be reached by

actual probing into the hole for cutting through the stem by hand and killed; plants may be subjected to acid fumes under cover like the treatment for scale insects in citrus trees; 'biological' control methods may be adopted, such as the introduction of parasitic flies, predatory birds and frogs, etc., as in the case of the sugarcane moth-borers, the 'fluted scale' on citrus, wattle or eucalyptus, the cocoanut leaf-eating pest, boll-worms on cotton, etc.; attacked portions may have to be cut away and removed, and so on—in fact, there is a large variety of methods applicable to particular crop pests and many of them are the result of close study of the life-history and habits of each pest with a view to finding out the weakest or most vulnerable stage at which they can be destroyed without difficulty. The chief point to be emphasised is that one should be conversant with the particular method suitable for his crop and be prepared to fight it, the small owner with small appliances and the large owner or planter with large-scale appliances.

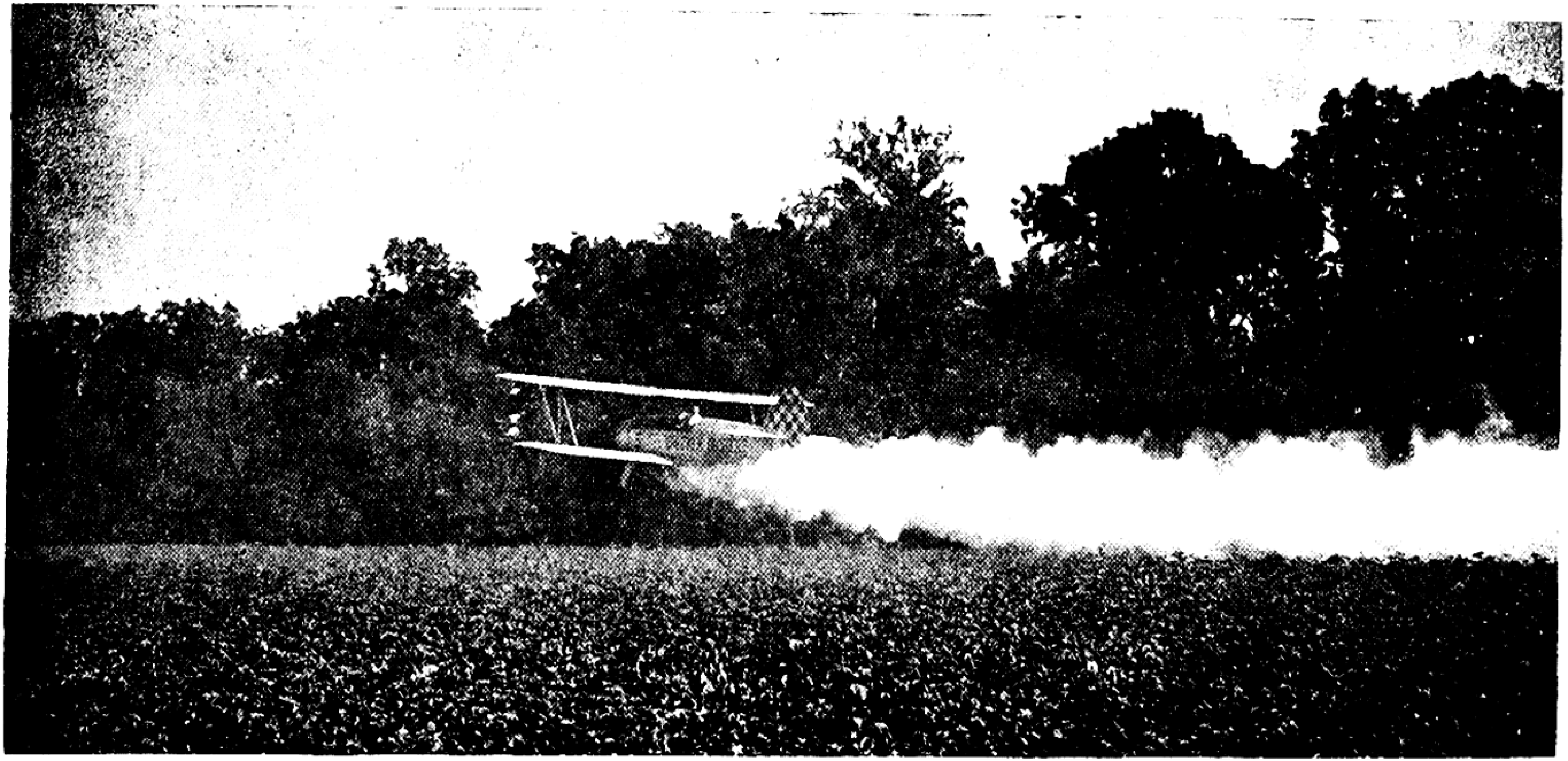
Pests which harbour underground present a separate and somewhat difficult problem; these may comprise white-ants and red-ants which have their nests underground, many beetle grubs and eel-worms. Remedies take the form of some kind of fumigation or sterilisation. The former is carried out with the cyanides of potash or calcium or the highly inflammable liquid carbon bisulphide. As a safety measure the latter is used in the form of an emulsion with cocoanut oil and soap in water.

Supervision and Timely Action.—It should be remembered that in all cases especially in small farms and gardens, if the pest or disease is noticed and attended to just when it breaks out, it will be easy to stamp it out altogether, for the pest increases so rapidly that later on it will be both difficult and expensive to control it. "A stitch in time saves nine" is a maxim very much applicable in such cases. Moths can be caught with hand nets, or light traps, grubs removed by handpicking, egg masses may be rubbed off likewise and so on, if the pest is noticed in the beginning itself, and a good deal of spreading of the pest can thus be prevented. Intelligent watchfulness and frequent inspection of the crop are of course essential for this purpose.

Joint Action.—Another point to note is the need for joint action by farmers or planters in the case of many pests and diseases. Where a pest is widespread, remedial measures by only a few people will not save the tract; in fact if all the men concerned do not adopt the method, the infection or source of the pest will always remain and the labours of the few will simply be wasted. Joint action by the whole community concerned will have to be enforced by law where voluntary co-operation is not forthcoming. Pest Acts in respect of particular pests and diseases are on the statute books of many governments for this purpose. In India the Central Government Act II of 1914 can be used to control importations. The State of Mysore has an Act to deal with the *Kole roga* of arecanuts and

The wingless aeroplane (Helicopter) used for spraying and dusting, in the same way as the ordinary winged planes but claimed to possess additional advantages. Picture shows a demonstration of a British machine.

By Courtesy of the Editor, 'Daily News,' Bangalore City



View showing the use of low flying aeroplanes, for the dusting or spraying of insecticides, fungicides and weed killers. It may be notable that dusting of 2, 4 D weed killer, by this method is now banned in the U.S.A. on account of the damage caused to crops and other vegetation by the wind borne drifting dust.

By Courtesy of E. J. Baker, Esq., of 'Farm Implement News,' Chicago, U.S.A.

of the coffee-borer beetle; in Madras the Pest Act is enforced against the cotton stem-borer and the *Nephantes* caterpillar on cocoanut trees; in Kashmir the Pest Act applies to the San Jose scale and the woolly Aphis, while Bombay has a very comprehensive Act appreciable to both pests and noxious weeds. Similar legislation is reported in other parts of India also.

Insecticidal Preparations.—Insecticidal materials or preparations are not many and it is a fortunate circumstance that the commonest ones capable of general application are easy to procure. These comprise ordinary ashes, soaps, kerosene oil, tobacco (waste, powder or cured leaf), sulphur, quicklime, etc., which are all obtainable in the bazaar, and lead arsenite, tar-distillates, Diesel oil, Paris Green, Pyrethrum powder and recently several proprietary powders and sprays containing D.D.T. (Dichloro diphenyl trichlorethane) and the very effective new insecticide called gammexane. The methods of preparing them for use are also simple; hand-spraying machines, dust guns for small-scale use, are also available, while spraying machines worked by hand or engine power and with attachments for projecting the spray over a wide area are available for large-scale work. Dusts and sprays are even beginning to be used nowadays with low-flying aeroplanes over large tracts of cultivated crops, orchards and forest trees.

Some Important Precautions.—The spraying or dusting of insecticides of different kinds, although adopted almost universally for crop protection, is not altogether without some risks, to which attention may be drawn. Where they are applied on to edible crops, whether vegetables or fruits for human food or as green feed for cattle, there is some risk which arises from the fact that the spray materials are poisonous or at least disagreeable and likely to prove injurious to health. If any deposit or coating of the material on fruits or other parts of the crop intended for consumption should remain as a film on the surface when they are gathered, then they should be washed thoroughly to remove the coating. Usually however considerable time elapses between the spraying and the gathering of the crop, during which they are generally washed off by rain, rubbed or blown off by the wind, etc., but as a measure of abundant caution it is advisable to wash them well before consumption.

In the case of the new 'wonder' insecticide D.D.T., much caution is very necessary. It keeps its deadly effect for a long time and as a contact poison it kills not only the insects which form the pest, but also any others including beneficial insects that may come into contact with it (like the honey bees for example). In some D.D.T. preparations it is found very injurious to the skin of the person or animal and may be fatal to domestic pets or animals licking the spray or dusted surface. It is put out in more than one form, such as an emulsion in water, or as a solution in petroleum distillate, or dust mixed with some innocuous filler, and also in different strengths, each of which has its own special application.

The instructions which always accompany the packets or tins should be strictly followed.

The most important among these, probably, is the synthetic compound, benzene hydrochloride, or hexachloro cyclohexane, also called 666. This compound forms the active base in many insecticides put up under different trade names, the best known among which is gammexane, as also B.H.C. It has been found so universally applicable and is put up in so many different forms suitable for spraying, dusting, and even as a smoke, that it is considered almost as a panacea against all insect pests. The greater therefore is the need to adopt the precautions noted above and to follow strictly the instructions which accompany them.

Another important and effective insecticide, likewise supplied under different trade names, has an organic phosphorus compound as its base. These are deadly poisonous to humans and livestock, and great precautions have to be taken to protect every part of the body from contact with them, by the use, for instance, of gas masks, goggles, gloves and roomy overalls, by all members of the operating staff. Their advantage is a very high potency and the need to use only very small or almost trifling quantities per acre. The insecticide called T.E.P.S. (which contains the active base, tetra-ethyl pyrophosphate) belongs to this class and is now being used against the coffee pest, green bug, on many estates. Only 5 lb. (dissolved in 450 gallons of water) are said to be needed per acre; but other insecticides of a similar type, now being used against cotton pests (in the U.S.A.) are reported to require as little as ½ lb. per acre.

Calcium cyanide and potassium cyanide sometimes used for killing white-ants and other ants, field rats and similar pests evolve a highly poisonous gas and one has to be particularly careful in handling and storing the material. Others may be highly inflammable either by themselves or on account of the solvent in which they are dissolved. In all cases instructions regarding nearness to open lights or flames accompany the packages or bottles and will have to be likewise strictly followed. On the whole some amount of knowledge and special care are generally called for in this matter.

A rather notable recent development is the use of "systemic" insecticides. These are applied as solutions to the roots of the pest-affected plants, which take them up much like manurial elements. Circulating in the sap of the plants and traversing all tissues, they are able to bring about the death of the pests feeding on the plants, whatever part it may be, whether roots, stems, leaves, flowers or fruits, and whether feeding by boring, sucking or biting. These are also highly poisonus organic phosphorous compounds and require great caution in handling and application. Some proprietary preparations of this class are Systam and Pestox and have as their active base the synthetic chemical, Di-methyl-amino phosphorus anhydride.

Plant Diseases

The diseases attacking plants are many and the general principles to be remembered in connection with fighting them are substantially the same as have been described for insect pests. The causative agents of the diseases are however more difficult to discover, infection more difficult to prevent, and remedial measures also likewise difficult and often drastic in character. The causative agents are (1) fungoid, (2) bacterial, or (3) virus, in origin. The infection may spread through seeds and planting material, through the wind, water, soil and through biting insects. Physiological causes such as faulty or insufficient nutrition may also set up diseases or abnormalities in growth practically amounting to diseases. Some diseases may be due to the presence or absence of what are called "trace" elements in the soil, and quite a few are very obscure in origin. Weather conditions also predispose or are favourable for the outbreak and spread of some. Some are very quick and devastating in their destruction, and may not leave any time for the application of measures of control. All in all, plant diseases are rather difficult problems and fairly baffling in many respects.

The remedial measures comprise as in the case of insect pests (1) to avoid infection, to remove the centre of infection and prevent it from spreading; (2) to kill out and destroy the fungus and to save the crop by spraying or dusting with fungicides; (3) to prevent infection through cuts and bruises, by protective painting or disinfecting the surface; (4) to give up growing for a few years particular varieties; (5) and crops susceptible to the disease so as to free the soil from the disease-causing organism; (6) to spray with insecticides in the case of diseases with an insect vector, so that these biting insects are killed out or repelled and further progress of the disease arrested; (7) to cut out and burn diseased plants, and all infected material; (8) to treat the soil so as to disinfect it or alter its reaction or correct the deficiency in the nutrition; (9) to improve the drainage; (10) to stop heavy nitrogenous manuring, both of which are often predisposing causes; (11) to supply the deficiency of a 'trace' element by manuring or spraying.

The above list is by no means exhaustive. As in the case of insect pests the chief thing is to know about the symptoms and the remedies applicable to the particular disease of the crops one may be largely growing, to be prepared with the necessary materials and appliances and to carry out the remedial operation promptly and effectively. The need for joint action among neighbours is as important as in the case of control methods for pests.

Some of the methods are very simple, such as the washing or dusting or steeping (using hot water, formalin, copper sulphate, sulphur, etc.) of seed grains like jowar, wheat, bajri, barley, etc., against some forms of smut, or the spraying with fungicides like Bordeaux mixture, lime sulphur, various sulphides, etc., on to low-

growing crops. The spraying of tall trees like arecanuts, mango, rubber (for fruit drop, mildew and leaf fall respectively) or the undersides of low-growing or creeping crops may be difficult, as likewise the cutting down and burning of large affected trees against stump rot, bud rot, etc.; but until simple remedies are found out one has to carry out the methods known and recommended, despite difficulties. When it is seen that even aeroplanes are being used to spray or dust affected crops in the U.S.A., it may be realised to what great lengths one has to go in fighting pests and diseases.

Immune Varieties.—Very often the growing of a variety of the crop which is immune to the particular disease is the only way in which the disease can be combated and much work has been carried out in securing such varieties either from foreign countries or more generally by evolving such varieties by breeding. In nature, varieties which are wholly or partially immune may be found, in which case the solution becomes easy; but where such varieties have to be bred then it is a question of time. The latter method is however more satisfactory because it may be possible to combine in the new variety both immunity and the special merit of the susceptible variety such as high yield or other quality, whereas in the former case such a combination may not exist. But even the arduous work of breeding the new variety is not free from further difficulties, as some of these disease-producing fungi exist in or possess more than one strain and a variety raised as resistant to one strain may not be so to another. Nevertheless the breeding of immune varieties is certainly the most promising line of work in combating some of these diseases. Wheat and other grains resistant to rust, cotton, tuver, sannhemp, etc., resistant to wilts, coffee resistant to leaf rust disease are some well-known examples (*see* also Chapter on "Improved Varieties and Crop Production").

The fungicidal materials, unlike the insecticides, are not common bazaar articles but have to be got out specially. Thus copper sulphate for making Bordeaux mixture on any large scale, the casein which is used as a sticker, flowers of sulphur, the various sulphides of potash, formalin, the proprietary materials like arasan, cerasan, agroson G.N. and the like (used for treating seed grain diseases like against smut, *Helminthosporium*) coal tar and tar products, paints and so on are all to be got specially. Quicklime which is required for mixing with copper sulphate or with flowers of sulphur is about the only easily procurable article. The spray pumps, dust guns or dusting machines are however the same as those as are required to fight insect pests. On the whole, pests and diseases form a formidable obstacle to crop production and one has to wage perpetual war against them.

Spraying for the Prevention of Fruit Drop.—Another kind of protection of produce relates to the prevention of the drop of fruits which takes place very prematurely in the earlier stages or when they are practically ready to pick and when their retention on the

trees will be desirable until they can be harvested in the regular way. Such prevention will mean a great saving of the year's crop, especially if it can apply to the fruit fall of the first kind. Fruit fall is now being prevented to a large extent by the method of spraying the trees with certain "growth hormones", the substances recommended most being naphthalene acetic acid and naphthalene acetamide. The hormone is to be applied in very dilute strength in water containing a little alcohol, but the commercial products already on the market indicate the exact manner of application. The spraying is to be applied to the stem or calyx end of the fruits, rather than to the leaves in the usual way so as to protect the vulnerable part concerned. The method has come much into vogue in the case of apples of many varieties for preventing the pre-harvest drop. Fruit drop in the earlier stages, which is due to various causes, is however the more serious form of damage in the case of many kinds of fruit trees in India, and it is a matter for experiment to find out if and to what extent, the method will be applicable in these cases. Present indications seem to be however that this kind of fruit fall is not amenable to the method, but the matter is still in the experimental stage in many of its aspects.

Losses to Stored Produce.—So far we have dealt with the pests and diseases attacking crops on the field. Even after they are harvested and stored the trouble is not over, because produce in storage is also subject to pests of various kinds and to damp and mildew, and the losses due to these causes are very great in the aggregate. The subject is separately dealt with in the chapter on "The Preparation and Storage of Produce". It need only be emphasised here that vigilance and timely attention in saving produce are called for at every stage.

CHAPTER XX

IMPROVED VARIETIES AND CROP PRODUCTION

AN important factor in crop production and one which is being made use of very extensively throughout the world is the improvement of crops and the growing of these improved varieties in the place of the older ones. The nature of the improvement whether it lies in the increased yield as is most often the case or in other special characteristics, is very great and striking, and the method involved in securing this advantage consists merely in sowing or planting the new variety instead of the old one, that is to say, a mere replacement of the seed and therefore one which entails no trouble or expense. As a factor in increased production it may be said to be the most popular; it is an improvement which spreads with remarkable rapidity and with very little outside stimulus or propaganda. It advertises itself. It may be said to rank on a par with the introduction and use of the artificial manures in increased crop production and in some respects even to excel it. The need for improving varieties is so great and the economic characters in which the improvement is sought are so many and so important that the field for research is very wide. The success which has already attended the labours of plant-breeders all over the world has been so great and even spectacular that this is probably the most popular branch of agricultural research. Great as the success has been, it is not altogether free from limitations or qualifications to which reference will be made later on.

LINES OF IMPROVEMENT

The improvement of the crop consists in the breeding or evolving of varieties which are superior to the existing ones. The superiority may relate to (1) increased yield; (2) change of duration, especially earliness of maturity; (3) hardiness or greater adaptability to special environment like particular soils, heavy or low rainfall, low-lying situations or the contrary; (4) special quality in produce, *i.e.*, a high sugar content in sugarcane, a finer or longer fibre in cotton, a high oil content or protein content or "quality"-conferring constituent in crops; (5) habit of growth such as dwarf or tall, to prevent being blown down or to increase the straw for fodder; (6) stiffness of straw to prevent lodging; (7) colour, size, shape, taste, etc., in flowers, vegetables and fruits; (8) resistance to particular pests and diseases. The improvements relate to practically every crop and in addition to the characters listed above, there may be others special to certain crops.

Some Examples.—Many examples of crop improvement by this method among agricultural crops and of the improved varieties which have been taken up on an extensive scale and are therefore

of outstanding importance can be given, while in respect of fruits, flowers and vegetables their number is legion. In India, the improved varieties of sugarcane evolved in the Sugarcane Breeding Station in Coimbatore and which are distinguished by Co. numbers are of all-India importance and have been taken up in many other sugarcane-growing countries of the world as well. The varieties evolved and released for general cultivation are very large in number and very varied in the qualities which they possess, such as in thickness, in tillering capacity, colour of rind, habit of growth, period of maturity, sugar content of juice and the tonnage per acre. The older varieties of cane in the country which have been under cultivation for centuries have now been replaced all but completely by Co. canes. The new canes of Java are world famous and have been one of the main causes of that island's pre-eminence in sugar production. Many other sugarcane-growing countries have also similar work to their credit.

Cotton varieties may be mentioned next, all of them bred principally for length of staple, high ginning percentage and some to wilt resistance. All provinces of India have evolved varieties suited to their conditions, which are steadily replacing the older varieties. In every cotton-growing country, steady and continuous breeding work maintains the high level of excellence of the varieties evolved. Even the famous 'Sea Island Cotton' is said to owe its long staple to systematic breeding by selection.

The so-called hybrid corn in the U.S.A., bred for high yields of up to 20% over others, strength of stalk, greater vigour, resistance to insects and diseases and maintained at a high level of performance by special seed growers, is being grown upon thousands of acres to the exclusion of the ordinary seed. Corn has been improved so as to contain a high percentage of starch, protein or oil as desired, the improved variety differing markedly from the ordinary seed in the percentage of the component desired. In oil content alone, the percentage of oil has been raised from about $4\frac{1}{2}\%$ to nearly 10% in the improved varieties, and the protein content from 10% to 15%. The sugar beet is maintained at a high level of sugar content by plant improvement methods and the percentage of sugar in the juice of the improved beet may go up to 16% to 18% of sucrose as against the 7% or 8% in ordinary specimens. Wheat has also been subjected to improvement in many respects like rust resistance, baking quality, high yields and so on. The number of improved varieties of many types in Europe is very large and some like the 'Wilhelmina', 'Little Joss' and 'Yeoman' are famous; in India also several good varieties of wheat have been evolved in (Bihar) Pusa and in Delhi. Other grains have also come in for improvement and many strains have been put out in the case of most of the Indian grains. Rice has a very large number of improved varieties evolved in nearly every province to suit the peculiar conditions of each. In South India the G.E.B. 24 of Madras is an out-

standing example. Pulses, oilseeds, fibres, tobacco and nearly every kind of crop are attempted to be improved and in many provinces special varieties have been bred and have been released for cultivation. Many of these are listed at the end of this chapter.

As far as the agriculturist is concerned in this important factor of crop production, what should be emphasised is that he should be alert in noting the new varieties produced and be quick to give them a trial and to adopt them if found really superior. It will be also possible with many intelligent and keen agriculturists to do their own little bit in the improvement of the crops they grow at least in maintaining the improvement, if not, with luck and once in a while, to hit upon and originate a new variety itself. There are many instances, especially in flowers and fruits, of varieties which have become famous but which owe their origin to the keenness of observation of ordinary growers. The variety of coffee called Kent's hybrid which is famous in South India for its resistance to leaf diseases and for its vigour and high yield is also an example of the same kind.

Methods of Originating Superior Varieties

The general principles which relate to plant improvement may now be described in broad outline. Plant breeding has become part of the science of genetics and highly specialised and suitable text-books will have to be consulted for a detailed account of both principles and technique.

Two methods are adopted in originating superior varieties of crops, *viz.,* (1) Selection, and (2) Cross-breeding (or hybridisation). Both imply the existence in nature of a large number of varieties either naturally and 'ready-made', as it were, or artificially produced by methods which will be described presently.

(*a*) *Varieties in Nature*

In nature all forms of life whether plant or animal tend to vary naturally and show accordingly slight variations in different characters. Such variation may be beneficial to the plant or animal or otherwise, in the sense that it enables it to adapt itself more or less to its environment; if beneficial, then the variation helps it to successfully survive in competition with those not possessing such variation and in the course of evolution becomes its permanent feature persisting from generation to generation. It then becomes a fixed or hereditary character. The large number of variations in cultivated or wild plants have arisen in this manner, and these are only a fraction of the huge numbers which should have perished in the struggle for existence. From the improvement point of view it is only those varieties in which the variation or character has become fixed or hereditary which are of any value.

Variations in one or more characters may appear and are common features of plant life, but such variations may be due merely to the environment such as more manure or some special plant food like lime, more light, more water, etc.; these variations will therefore disappear with a change in the environment, that is to say, the character will not be transmitted. Some variations may on the other hand be permanent or hereditary and such plant will transmit the character to its progeny. It is only then that the plant with the special character can be called a 'variety' and the character called a varietal character. Even the first kind of variation (sometimes called 'morphological' variation) is not without some practical importance, because under the same kind of environmental conditions the variation will be reproduced. In *hydrangea,* for example, blue colour can be induced in the flowers by heavy liming of the soil. As a matter of fact in actual crop rising one always tries to grow them under the best conditions, and these variations therefore have a chance of persisting.

The varieties which are produced and are to be seen in nature are the most important and most numerous and furnish the largest mass of material for selection either as an introduction pure and simple or as the starting point for improvement. In fact it is probable that the best among the varieties improved by selection are already existing in nature. It is these varieties that one has to be on the lookout for always, and it is a fortunate circumstance that in most cases they are conspicuous and easily strike the eye.

(*b*) *Artificially Produced Varieties*

1. In the case of plants which are propagated from seed and which are cross-fertilised in nature more varieties are likely to be seen on account of the mixed parentage and the many different ancestral characters pure and mixed in various proportions may be expected. Arising out of the same principle, varieties can be produced artificially, if a plant which is propagated only vegetatively (under cultivation) like sugarcane or potatoes is propagated from the true seed. While in the vegetative propagation in the usual way the progeny is all exactly like the parent, in propagation by seed, the progeny will be quite different and be a mixture of many kinds, differing in various characters and degrees from the parent, including those which may be exactly similar to the parent. There are however some interesting exceptions as in the case of the so-called polyembryonic seeds (seen among mangoes and citrus fruits), in which only one may be a true seedling and may therefore be different from the parent and of mixed blood, while the others (one, two or more) are in the nature of vegetative seedlings and breeding quite true to the parent (seedlings from single polyembryonic seeds in citrus trees may go up to 12, while about 6 will be an average).

Other methods of artificially producing varieties are :—

2. Varieties may be produced by crossing two varieties which though pure and each breeding true to its own parent, will yield a large mixed progeny in which the characters of either parent in varying proportions may appear. The first generation cross may sometimes be identical (in appearance) with one or other of the parents, but the seeds of these plants have the hidden or latent potency of yielding varieties of mixtures when propagated from.

3. Varieties may also be originated by subjecting seeds or planting material to the action of X-rays or of various chemical agents, the chief among which is colchicine. The treated seeds when sown give rise to plants many of which are quite different from the parent and are true varieties; likewise the vegetative buds on the planting material or sets grow into quite different plants from the parent giving rise to a set of completely new varieties.

4. Varieties may arise by some part of a plant differing strikingly from the rest, such as in colour, shape of leaves or flowers, fruits, etc. These parts if removed and propagated vegetatively will transmit the variation and be therefore a different variety altogether. Some new varieties of sugarcane, many ornamental foliage and flower plants, and the famous 'Washington Navel' seedless orange, owe their origin to this form of variation; the name 'bud variation' is applied to this kind of variation and the new variety is called a 'bud sport'.

Sometimes a new variety may come into existence in an otherwise uniform type, quite unexpectedly, and can become a true variety breeding true to the new character. The name "mutation" is given to this phenomenon, and the appearance of 'mutants' is therefore another source for varieties to originate.

It is upon the large amount of material in the shape of the many varieties existing in nature or raised artificially that improvement has to be worked. The numerous cultivated crops owe their existence as superior varieties over the wild poor ones in nature to some process of selection, perhaps unconscious, by civilised mankind through the centuries. Modern methods of improvement are purposeful and systematic and attain the desired results within a very short time at any rate within the course of a few years.

Assessing Varieties by "Performance Records"

The qualities or characters in which one plant or variety excels the other and which it is desired to improve or perpetuate are either readily seen by the eye and attract notice or have to be found out and estimated quantitatively and their superiority properly assessed only by special methods. Characters like habit of growth, shape, size, colour of the leaves, stems, flowers or fruits are readily seen by the eye or in respect of taste and flavour by the tongue. Even important characters like resistance to pests and diseases can readily be seen by the eye. Other characters like the

yield of the produce such as grain or fruit or other substances like rubber, cinchona, complex essential oils or other special products of certain kinds of trees have to be found out, for purposes of being used as material for selection and improvement, by means of "performance records" of individual plants. It will be found that the variation in regard to most of these substances is very large and striking as between individuals. Selection for being made use of as parent or mother plant will therefore require in such cases a systematic individual performance record.

Other characters like the special constituents of produce like oil content, sugar content, protein or starch content or of special active principles for which the crop may be cultivated will require assessment by means of chemical tests and a performance record with regard to the content of such constituent in individual plans.

Plant Introductions

As already stated the methods of improvement comprise selection and cross-breeding. It is sometimes usual to include among them the method of mere introduction from a different country or region of a new variety which may appear superior in some desired respects to those already existing or the indigenous ones. Obviously this is the easiest line of work and can hardly be dignified by the name of a method, at least in comparison with the other two. Nevertheless many remarkable instances of such introductions can be quoted from different countries in the world and the possibility of such introduction has always to be kept in view. In the U.S.A. a special Bureau of Plant Introduction is maintained, which surveys plant life in many countries, imports desirable ones, tests their value and acclimatises the best among them. In recent years many governments are sending out special expeditions for plant collection, especially wild hardy species, which may be used as foundtion material for breeding work.

The method of plant introduction is not without its drawbacks and some very serious too. The most important among the latter is the introduction along with the variety of new diseases or pests, and among the former is the risk of the variety not being found suitable. Sometimes the plant or variety may find ideal conditions in its new home, and spread like a jungle growth or weed and get quite out of control. Probably the most important among varieties introduced into India from foreign countries, is American cotton (*Gossypium hirsutum*) and it illustrates the limitations of the method admirably, because in spite of the facts that it has been cultivated with assiduity and care during a period of some 150 years and that much intensive research work has been carried out upon it, the variety still remains subject to both diseases and pests which baffle treatment and which keep down its otherwise undoubted merits, in respect of high yield, superior colour, length and quality of lint.

Selection

In the method of selection, attention may be paid to any one particular character of the plant and attempts made to intensify or accentuate this character by carrying out the selection through several plant generations. For example, if it is the size of the pod which it is intended to increase, then the plants with the largest pods alone are selected for seed purposes and sown again; in the next generation also only the plants with the largest pods are selected for seed purposes and in the next generation raised from these seeds the selection is repeated. Such a process results in a type of plant in which the plants bear much larger pods than those from which the start was made. Similarly if we wish to select for three-seeded pods in groundnuts, for example, the seeds for sowing purposes are taken from only such pods and the process repeated through two or more plant generations; the resulting type evolved is one which consists mostly of such pods in contrast with plants in the unselected lots in which this is not the case. Again if we wish to select for large earheads in a grain like ragi possessing five or six spikes, plants with the largest earhead alone are selected for seed and these are propagated from; in the resulting plants also a similar selection is made and the process repeated through several generations in order to obtain a type in which the generality of the plants bear such earheads. Selection may be made for other characters like the length of staple in cotton or the content of starch in maize or the oil content in an oilseed and only such seeds planted as have come from plants the seeds of which showed the particular character in a high degree and excelled the others or the bulk and the selection is repeated year after year. In the same way in the case of sugar beet only those roots are used as seed bearers or mother plants which showed a high percentage of sugar; the selection is made through the several generations of increasingly rich sugar beets until a type is evolved whose sugar content is much higher than the one from which the start was made. It is indeed a case not only of 'like begetting like' but also of the progeny excelling the parent in successive generations though only in minute degrees.

It must be stated that, despite the record of successes in the past, the possibility of effecting improvement successively in this manner is doubted, inasmuch as there is an inexorable limit to what may be expected. No monstrosities either in largeness or smallness for example in fruits or pods can be produced and the feature cannot be altered to any extent or in any manner which may be detrimental to the plant, or make it less capable of surviving competition. Indeed many of the improved characters are such as cannot help the plant in competition with the unselected or bulk plants, and in order to keep up or maintain the improvement, the selection will have to be continued year after. Otherwise the general tendency will be to gradually deteriorate to the level of the unselected type.

Mass Selection and Individual Selection.—The method described above is referred to as "mass selection" and it has to be distinguished from "individual selection", which is explained below.

Selection (or any other method for that matter) is useful only to the extent that the improvement in the character is transmitted or progressively increased in the progeny from the selected seed and this capacity to breed true to the character concerned is a very important requirement. Plants vary very much in this respect in this important quality, which depends upon how the plants are fertilised in nature, that is, whether self-fertilised or cross-fertilised. In the case of self-fertilised plants the progeny is quite like the parent but in the case of cross-fertilised plants there is always variation in the progeny. Even in the case of the self-fertilised plants, if the selection is made from many plants, the improved seed so collected consists of the produce from many plants, all of which may not be equally good or in which the character selected for may not be varietal but only due to environment. In technical plant breeding work more reliable methods have to be adopted and these methods take the form of making "individual selections", *i.e.,* seeds being selected separately from many *single* plants possessing the desired character and of sowing these different lots of seeds in separate plots or lines under uniform conditions and then judging their performance. Final selection is made only from the best or those high yielding lines or plots (if the yield is the character for which selection is made) and it is these seeds which are multiplied and released for general cultivation.

Furthermore it is established that in the case of self-fertilised plants the character is so fixed that no variation takes place in the progeny and that therefore any successive improvement as is sought to be effected is not possible. The practical result of this circumstance will be that there is nothing to be gained by any further attempt at selection, such as we have explained above. On the other hand it is also to be noted that even among the progeny of individual plants selected and grown in pure lines, there is a certain amount of variation, *i.e.,* not all the plants are alike but the progeny vary a little in either direction from the parent type. The name "fluctuating variation" is sometimes given to this variation. A selection of the best among these therefore may be expected to keep the level of the improvemnt high or to keep the mean round which the fluctuation takes place as high or near the parent as possible. It may be going too far to enter into a discussion of these aspects of plant breeding work further.

It is enough if we remember that the "mass selection" which we have described so far does, under the usual conditions of field husbandry, result in undoubted benefit, certainly in keeping up a high level of performance, if not in any further or additional improvement. It is a method therefore both worthy and capable of adoption

by the intelligent agriculturist as quite an important factor in increasing crop production.

Selection and Vegetative Propagation.—While propagation by seed is thus subject to these limitations and difficulties, in the case of plants that can be or are usually propagated vegetatively the work is free from complexity, is easy of being carried out and yields striking results. If a variety exceptionally good in one or more respects is found in nature and if it can be vegetatively propagated by budding, layering or by cuttings, then it can be multiplied readily so as to yield plants, every one of which will be like the parent. For example, all the numerous varieties of seedling sugarcanes of outstanding merit which have now come into cultivation have been rapidly multiplied from the variety originated, by the simple method of planting cut pieces (or seed sets) from the parent cane. If any exceptionally good variety of potato should result when the true seed is sown in order to originate new varieties, then that variety can be multiplied by planting the tubers cut or whole, and every plant resulting therefrom will be like the parent. In the case of crops like the various fruits such as oranges for example, a specially good tree is propagated by 'budding' or the union of buds taken from it on to ordinary stock. Bud wood of such selected trees is sold and in some countries such trees are registered and recommended to growers wishing to raise new plants or renovate old ones. A most remarkable development of the method is to be seen in the case of budded rubber, the bud wood being derived from parent trees whose performance has been carefully recorded and found to be very high in the yield of rubber. The bud wood called "clones" is now supplied on a large scale as an article of commerce by well-known plantations. When it is remembered that budded rubber trees from good clones yield twice or three times the quantity of rubber per acre as that from ordinary seedling rubber trees, this popularity of budded rubber can be readily understood. Many ornamental foliage plants with variegated or abnormal colours, flower plants like the rose, chrysanthemums, dahlias and the like, all lend themselves to improvement by vegetative propagation.

A noteworthy attempt at vegetative propagation which has been successfully carried out relates to coffee plants, on the Coffee Experiment Station, Balehonnur (Mysore State). Special technique has been worked out for the rooting of cuttings and many plants of outstanding merit whether of yield or disease resistance have been propagated in this manner.

Some Seedling Characters as an Index of Produce Character.—In the case of the trees which may take many years to yield their produce like fruits, rubber or other produce, one has to wait this long period of time before their performance or other quality can be judged and their suitability to serve as a mother plant decided. In some rare cases some particular feature of the plant such as the shape or the colour of the leaf or stem, the habit of growth or the pre-

sence of any particular constituent of the sap or tissue is found to be positively correlated with the quality desired in the produce. In that case a selection of the mother plant can be made at a very early stage and much time saved. An instance is the shape, size and colour of the eyebuds in sugarcane, which are characteristic of particular varieties and form to some extent an index to the quality of the cane as it may develop when fully grown. In cereal grains the pink or red colour of the node is correlated to the colour of the grain and serves in the seedling stage itself as an index of the colour of the grain; plants can therefore be discarded or retained in the early stage itself, according as the quality is desired or not.

It is also stated that in the case of rubber, the nature of the latex vessels in the young rubber seedlings is correlated with its future performance or rubber yielding capacity and that an expert examination of the plants at this young stage can lead to correct valuation of the plant as a future clonal parent.

Cross-breeding

The second method of plant improvement is by cross-breeding. This method aims at a combination or blending of the desired characters present in two different varieties in a single variety, in such a manner that the new variety will breed true to these combined characters.

One or other of the varieties is made the male parent and the other the female parent, sometimes without distinction, either variety being made use of as the male or female parent. Out of the progeny, those which possess the combined characters desired in the most pronounced manner are selected and are bred together so as to obtain another generation in which the desired type is approximated to, to a greater degree than in the first. The process may be continued until all or a large number among the progeny are of the desired type. The method is based upon the principle that 'like begets like', and so, the more the parents show the desired characters the greater is the chance of the progeny being similar. Sometimes instead of the progeny being bred together they may be back-crossed to one or other of the parents, so as to accentuate any one character. The method has long been practised in the case of domestic animals like cattle and sheep, and with such great success that many special breeds of outstanding excellence have been evolved in this manner. The use of the method in plant breeding is comparatively recent, but a great and rapid development has followed, chiefly due to the discovery of certain fundamental principles or laws governing heredity and the transmission of characters, thanks to the work of Gregor Mendel. The result has been that while formerly the method was largely haphazard and there was a large element of chance in the success, in spite of the great practical judgment of breeders, it is at present amenable to scientific control, in such a way that the result can be predicted. The fact that the calculated

and predicted result is found to be identical or closely approximating to the actual, has invested Mendel's theory with the force of a natural law.

Mendel's Work.—An example may give a fair idea of what Mendel's law teaches. If a variety of any plant (Mendel worked with peas) which is pure in the sense that its progeny will invariably breed true to a particular character, tallness, for example, is crossed with a dwarf variety of the same plant (also pure to this dwarf character) and if the seeds of the cross-bred plant are sown, it is found that all the resulting plants are tall. Mendel actually worked with peas of a 1′ variety as 'dwarf' and a 6′ variety as 'tall'. He found that the progeny were all from 6′ to 7½′ in height.

The older breeders will probably have suspected that the cross had not 'taken'. Mendel however sowed the seeds obtained from the cross-bred tall plants, and raised a progeny therefrom. On examination these plants were found to be a mixture of two different types of plants, one tall and the other dwarf, so that the tall plants of the first cross were really a cross but that the tall character in a way overshadowed or masked the dwarf character (and not that the crossing was not successful or did not 'take'). Furthermore on a numerical examination of this mixed population he found that there were three times as many tall plants as dwarf plants, that they were in fact in the proportion of 3 : 1. He continued the work and raised progeny from the tall plants of this generation, and the dwarf plants separately, and obtained a third generation. In these he found that (*a*) that all the dwarf parents had given only dwarf plants, *i.e.,* they bred true; (*b*) that among the progeny of the tall plants, one-third had bred true, *i.e.,* gave tall plants; and (*c*) two-thirds had again given both tall and dwarf plants. Mendel studied in the same way many other characters in the pea plant, such as size of seed, shape of seed (smooth or wrinkled), colour of seedcoat (white, grey, brown, etc.), colour of unripe pod (green or yellow), manner of flowering (axially or as a cluster at the top). To all these the name "unit" characters have been applied and Mendel's study related to these "unit" characters. This will have to be sharply distinguished from the character of the individual plant (which is composed of many unit characters) and the distinction will always have to be borne in mind. To the character ('tallness' in the example) which appeared in the first generation to the exclusion of the opposite ('dwarfness' in the example) the name 'dominant' was applied, because it so overshadows the other. The 'dwarfness' was by no means extinguished, it remained only latent, so to speak, or not visible to the eye. To this character was given the name 'recessive'. Using these names the result of the work may be expressed thus: The first generation cross or F_1 consists of dominants (tall); the F_2 or second generation cross consists of dominants (tall) and recessives (dwarf) in the proportion of 3 : 1. Mendel discovered further that although these three dominants were *outwardly* alike they were

different in *reality* (or genetically), because he found on raising a further generation (F_3) that only one among these three bred true, *i.e.,* tall and two others split into tall and dwarf; in fact the ratio in the F_2 was really 1 : 2 : 1 of 'pure' dominants, 'impure' dominants (cross or hybrids) and 'recessives' respectively. The F_2 generation progeny thus consists of $\frac{1}{4}$ like the one parent, $\frac{1}{4}$ like the other parent and $\frac{1}{2}$ like those of the F_1 or cross. The recessive always breeds true, while the dominant is a mixture of those which breed true ('pure' dominants) and those which split again ('impure' dominants).

The first cross may not always be like one of the parents (in respect of the unit character concerned) as in the above example; it may be intermediate between the two or quite different from either, so that there is no visible dominance of one character over another. But in the F_2 these characters will segregate (or separate) and appear in the following proportion : 1 like the one parent : 2 like the cross-bred; 1 like the other parent. The first and the third will breed true to their respective unit character, while the second will continue to split or segregate in the same proportion of 1 : 2 : 1 when bred together. The first cross in some cases may have an appearance, quite different from either parent and one which may be highly prized such as say some beautiful colour in flowers but they will be disappointing as regards true breeding, because the offspring may be like the one parent or the other parent or like the cross-bred itself. If, for example, a pink colour in a flower is the result of a cross between white and red flowers, then the pink-flowered plants will not breed true; but will give all the three colours in the progeny, *viz.,* some plants bearing red flowers, some white flowers and some pink flowers and if the progeny is numerically studied it will be found that they are in the ratio 1 of red : 2 of pink : 1 of white. It also follows from this theory and will be found (we cannot go further into the explanation here) that if the pink is black-crossed with either parent, then the progeny will consist of pinks and reds or pinks and whites in the ratio of 1 : 1. If instead of these colours, a dominant character like tallness in the first example is considered and the impure (the first cross) dominant tall is back-crossed with the pure dominant parent tall plant then it will be found that the impure dominants and the pure dominants will be in the ratio of 1 : 1 and will all *look* alike, *i.e.,* only tall; if on the other hand the impure tall dominant is crossed with the recessive parent (dwarf), then also the progeny will be in the ratio 1 : 1, *i.e.,* one half being tall and another half dwarf.

In practical breeding it is the individual plant which is to be improved, in respect of one or many (many rather than one) and the method in which each of the unit characters behaves in crossings will have to be studied, before a desirable combination can be evolved. In the case of many Indian field crops such studies have

been made and it may be of interest to note the following among them :—

1. In rice, round shape (in 'sirumani') has been found to be dominant over long oval shape, red colour of grain over white; straw yellow colour in paddy over red colour; lateness of duration over earliness; starchy grain over 'glutinous' grain; and non-shedding of grain over shedding or shattering.

2. In jowar, the purple colour in the glume is found to be dominant over the brown colour; yellow colour in grain over white; red colour over yellow; and tall habit over dwarfness.

3. In Bengalgram, pink colour in flower is found dominant over white and yellowish brown coat of the seed over bluish brown.

4. In chillies, red colour of ripe fruit is found dominant over yellow colour and pendent position over the erect position.

5. In toria, brown colour in seed is found dominant over yellow, and hairiness in the leaves over smoothness.

6. In cotton, presence of lint is found to be dominant over absence (as in the wild cotton); fuzziness over smoothness; the presence of the eye in the flower over the absence; long staple over short staple; deep colour in petals like red or canary yellow over light colour or creamy white, etc.

7. In gingelly, black seedcoat is found dominant over brown and both over brown.

8. In groundnuts, procumbent habit is found dominant over erect; large pods over small; many-seeded condition over few-seeded in pods; red seedcoat over brown; and late maturity over earliness.

Combinations of Many Unit Characters.—When as in practice, more than one pair of unit characters are concerned, the number of types in the cross-bred progeny (with regard to this particular set of unit characters) will increase. Thus if two pairs are concerned, such as, tallness and dwarfness and red- and white-coloured flower (for example) then there will be four combinations, *viz.,* red-flowered tall, red-flowered dwarf, white-flowered tall and white-flowered dwarfs; if one more set of characters is added then there will be 8 combinations and if four sets are concerned then there will be 16 combinations possible. When it is remembered that an individual plant is a combination of many characters all of which combined mark it off from another, the number of unit characters becomes very large and the cross-breeding becomes correspondingly complex. In practice, however, it is generally one or two sets of characters that are taken up for evolving a new type, such as for example, tallness with stiff stems, non-shedding with hardiness, awnlessness in grain with high yield, high ginning percentage with length of fibre, disease resistance with high yield and so on. In the case of sugarcane, which is propagated vegetatively, even though many characters are shuffled about, plants which possess the ideal combination can

be readily identified, isolated and propagated with the combination being transmitted intact.

The great point brought out by Mendel's theory is that the unit characters are transmitted *intact,* there is no dilution or division into half and half as between two parents and a further division in a succeeding generation. There is always the possibility of any of the characters (which though it is not apparent is still 'in the blood' so to speak) appearing in any later generation pure and undiminished but quite unexpectedly, in the manner of what used to be called 'atavism' or 'reversion' or 'throw back'. The study of the ultimate germ and body cells of plants has traced these hereditary characters or "genes" to the chromosomes in the nucleus of the cell and the origin of new variations to a crossing over and recombination of the genes, during the process of fertilisation or mingling of the male and female germ cells. Each species has a definite fixed number of chromosomes and all plants belonging to it carry the same number, whatever the variety therein may be. Thus rice has 24 chromosomes, ragi 36, jowar 20, maize 20, chillies 24, groundnuts 40, tuver 22, sugarcane 80, cotton (herbaceum) 26, cotton (hirsutum) 52 and so on. New species (as distinguished from varieties) can arise only by a doubling, trebling, etc., of the number of chromosomes, and crossing between these generally leads to sterility in the progeny. These matters belong to the subject of genetics and are beyond the scope of this book.

Interspecific Crosses.—It may however be stated that such wide crosses have also been successfully accomplished, to which a brief reference may now be made.

In Mysore, much important work in this direction has been accomplished with cotton. Interspecific crosses have been evolved between *G. arboreum* and *G. herbaceum,* between the *G. hirsutum* and *G. peruvianum* and also between *G. cernum* and *G. obtusifolium.* A valuable line in this work is the crossing of cultivated forms with their wild forms, by means of which very useful characters especially hardiness or disease resistance can be introduced into the cultivated species. In many cases such crosses are characterised by great vigour and increase in size, in marked contrast with either parent. Even wider crosses, as between individuals belonging to different genera (called intergeneric crosses) have also been successfully accomplished. In India sugarcane crossed with jowar and with the bamboo (in Coimbatore) and sugarcane with Teosinte (in Mysore) are examples. In Russia many such crosses are said to have been effected, the most notable being a cross of wheat with couch grass (*agropyrum*), which has been found among other things to be a fertile hybrid and a perennial. "These perennial wheats," says N. Tsitsin, the author of the hybrid, "have the unusual power of growing again after reaping.... With three years continuous vegetation these hybrids yield seven or eight harvests from a single sowing."

INDIAN EXAMPLES OF CROP IMPROVEMENT

Reference may now be made to some of the many improved varieties put out by the agricultural departments in different parts of India, in addition to those already referred to earlier in this chapter. A large number of them are evolved by "selection" but some have been evolved by the more elaborate method of "cross-breeding" also.

Wheat.—In wheat may be mentioned (1) the crosses with kapli wheat and ordinary wheat raised in the C.P. for rust resistance; (2) the Niphad (of Bombay) which is a high-yielding wheat raised as a cross between P_4 and a local selection called 'Bannuplali'.

Jowar.—Outstanding work has been done in Madras and strains like A.S. 29, A.S. 1093 and A.S. 389 are good strains among both rain-fed and irrigated varieties. A cross-resistant to Striga has also been evolved.

Bajra.—In bajra early and late types have been evolved in the Panjab. In Madras improved strains like P.T. 17, P.T. 248 and P.T. 728 are reported noteworthy.

Barley.—Likewise in the Panjab short-strawed and high-yielding varieties and a similar one with a high grain 'quality' have been raised.

Rice.—In Madras the G.E.B. 24 has become famous. Many selections among the several varieties grown in the Province have been raised for special qualities like resistance to Piricularia, drought or poor water supply conditions, earliness, etc. In the other Provinces of Bombay, U.P. and Mysore, many noteworthy selections have been evolved, which are in general cultivation. In Assam cross-bred varieties named 'Andrewsail' and 'Keresail' have been raised which are said to be superior to the older varieties in many respects.

Ragi.—Popular selections in Mysore are the H_{22}, H_{40} and others, while in Madras E.C. 593, E.C. 3517 and E.C. 375 have been evolved, the first being very popular.

Cotton.—A very large number of selections and cross-bred varieties have been evolved practically in every Province. In Madras selected strains have been evolved for all the different local cottons, Karunganni, Mungari, Nadam and Coconadas; in American cotton the Cambodia strain Co. 2 has become famous, and equally good strains are Co. 3 and Co. 4. In Bombay, selections in local or Kumpta cotton for staple length and for wilt resistance are well known; many Broach selections and a cross of some of these with Goghari raised for wilt resistance and fibre length; Gadag and Co. crosses for resistance to red-leaf blight in the D.A. cotton are also noteworthy varieties. In Sind many selections like 289 F, 285 F, 4 F and M 4 are popular selections from the American Upland cotton of the Province and the last one M 4 is claimed to be both early-maturing and resistant to 'jassid' fly attack. In Panjab the

selection called 39 Mollisonii from the local cotton has been raised for early maturity, high yield and high ginning percentage; among cross-bred varieties are 'Jubilee', a cross between the local and the 'Million Dollar' and also a cross of the 'Jubilee' with Nigerian cotton; many selections likewise have been raised from the local Panjab-American cotton. In the U.P. are the selections called C. 520 from the local cotton and a new type called Perso-American. In Mysore, selection 69 (local cotton), H. 190 (a cross between selection 69 and *G. arboreum*), M.A. cottons which are crosses between D.A. cotton and *G. peruvianum* are among the many types evolved.

Castor.—High-yielding strains have been raised by selection in many of the local varieties of castor in the Hyderabad State.

Toria.—Selections combining both high yield and high oil content have been raised in Panjab.

Sugarcane.—The Co. canes raised in the Sugarcane Breeding Station, Coimbatore, are world famous and the best among them have displaced the local canes all over India. Co. 290, Co. 312, Co. 213 among thin cane varieties; Co. 347, Co. 331, Co. 313 among medium thick canes, and Co. 421 and Co. 419 among thick cane varieties are of outstanding merit. Co. 351 and Co. 357 are cane varieties raised by cross-breeding sugarcane with sorghum, while H.M. 661, a Mysore bred cane is a cross between the sugarcane Co. 28 and Teosinte. Mysore has many varieties to its credit, such as H.M. 320, H.M. 544, H.M. 661, H.M. 647 and so on, among which some have been the result of X-ray treatment of the planting material.

A Note of Warning

The advantage resulting from growing an improved variety is generally so great and striking and is obviously such an inexpensive method that as a factor in crop production it may receive exclusive attention, other factors being either neglected or insufficiently attended to. It should not be thought that because a new variety gives such a high yield it will be enough if the mere sowing of this variety in preference to the old one is all that is required. This is not so and a note of warning or caution is necessary, as the idea is rather general.

Better Varieties Need Better Manuring, Watering and Other Attention

It must be remembered that a high-yielding variety implies a larger drain on the fertility of the soil in the shape of not only increased produce but also the much increased vegetative growth which generally accompanies it. This will necessitate the application of larger quantities of manure. It is true that a high-yielding variety owes its superiority to the fact that it can utilise the plant foods in the soil more efficiently than a poor one, but obviously it

can do this only if the plant foods are present in the soil, which can be secured only by heavier manuring.

It has also been noticed that some improved strains can show up their superiority or special character only at particular levels of manuring, or that "the yield potentiality of some varieties can be determined under conditions of high farming only" (Hunter and Leake in *Recent Advances in Agricultural Plant Breeding*). The improved Pusa wheats for example, do not give a very markedly higher yield over the local ones under the ordinary conditions, but it has been observed (by one of these authors) that when the variety follows a sugarcane crop in the rotation, *i.e.,* a heavily manured crop, the yield rose to double or even more than double the normal yield.

What applies to manuring applies to other factors of production as well, water being the most important among them in India. Along with adequate manuring therefore sufficient irrigation (or rainfall) should also be available, when a high-yielding variety is grown.

Even otherwise these superior varieties have to be given as far as possible the same conditions, whether climatic or soil, under which their superior features were evolved. For example, it is known that in cotton the fibre quality is much influenced by the manure or the soil factor, and that in rice the quality of the grain, such as coarseness or fineness, is also likewise influenced by the soil and manuring, while earliness and lateness are also greatly conditioned by climatic factors. Some of the famous Co. sugarcanes, for example, were not found to show up well at all on the sugarcane block in the Hebbal Farm (Mysore). All these limitations have to be borne in mind, especially the fact that manuring and irrigation are particularly important, in the replacement of poor or mixed varieties and strains by improved ones. Other factors cannot be ignored altogether either; in fact, as observed by the same authors, "so closely are the efforts of the plant-breeder and of the agriculturist interlinked".

CHAPTER XXI

OTHER IMPLEMENTS AND MACHINES

ONCE the field has been intercultured and weeded for the last time, the crops need little further attention, except watching and in the case of irrigated crops regular watering. The next field operations are those connected with the harvesting or gathering of the crop.

HARVESTING TOOLS AND APPLIANCES

(a) Present Methods

The harvesting of the different crops is carried out at present only by manual labour and the tools used are only ordinary sickles, the cutting edge of which is specially serrated for this purpose. They vary slightly in shape in different parts of the country, but they are all adapted to cutting only one handful of the stems or stalks of the grain crops at each cut and to be used by labourers in a sitting posture. This kind of harvesting needs a large labour force, and as the harvesting has to be carried out quickly and almost simultaneously in each tract, the demand for labour is very great, the work becomes very expensive, and labour too very difficult to get even at high wages, notwithstanding the fact that, attracted by the high wages, large gangs migrate for the season from the towns for the purpose.

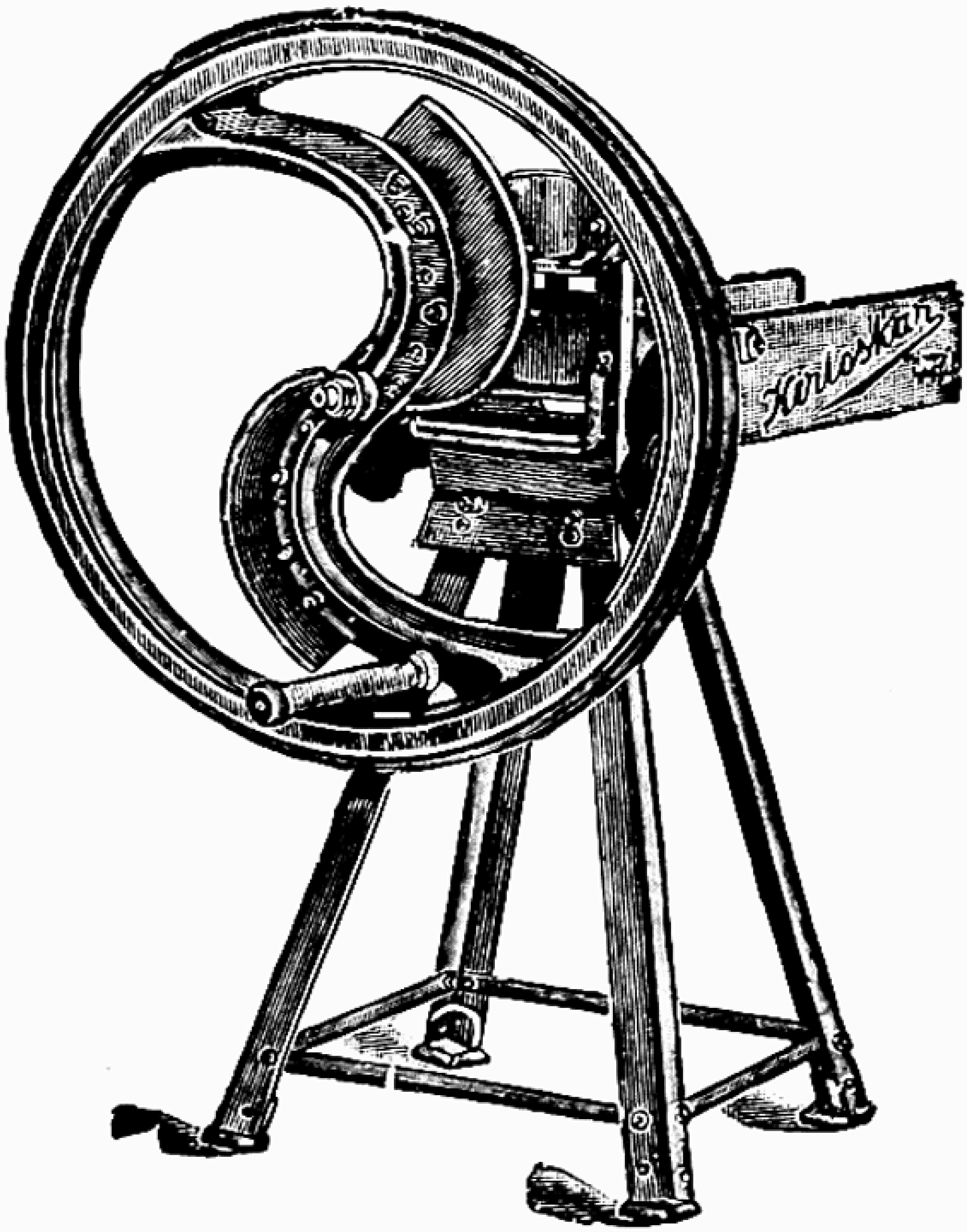
As against these disadvantages the method has the following advantages, *viz.*, (1) Where mixed cropping prevails as it does almost universally in India in the case of most crops, selective harvesting has to be carried out, because the main crop alone is ready for harvest while the subordinate crop matures only some weeks later and has therefore to be left standing. This selective harvesting can be done only by manual labour in the present manner. (2) The grain crops other than bajri and jowar are weak-strawed and lodge very badly; a heavy crop of rice at harvest time lies almost flat on the ground and others like ragi or Italian millet are scarcely better. Under these conditions only the present method can be thought of for handling the crop. (3) In the cultivation of rice, the fields are very small, divided by prominent bunds and often at different levels like terraces; the surface of the field is wet and soft and may not generally permit of a heavy machine travelling over it. These conditions suit only the present practice. (4) With hand tools the harvest can be done with great economy and care, the stalks being cut very close to the ground for saving the straw and all knocking about of the stalks prevented and shedding of grain avoided. These features appeal very strongly to the thrifty ryot, who will not leave a single stalk or broken earhead in the field but will carefully glean them after the harvesting coolies have left.

(b) Improved Methods that may be Considered

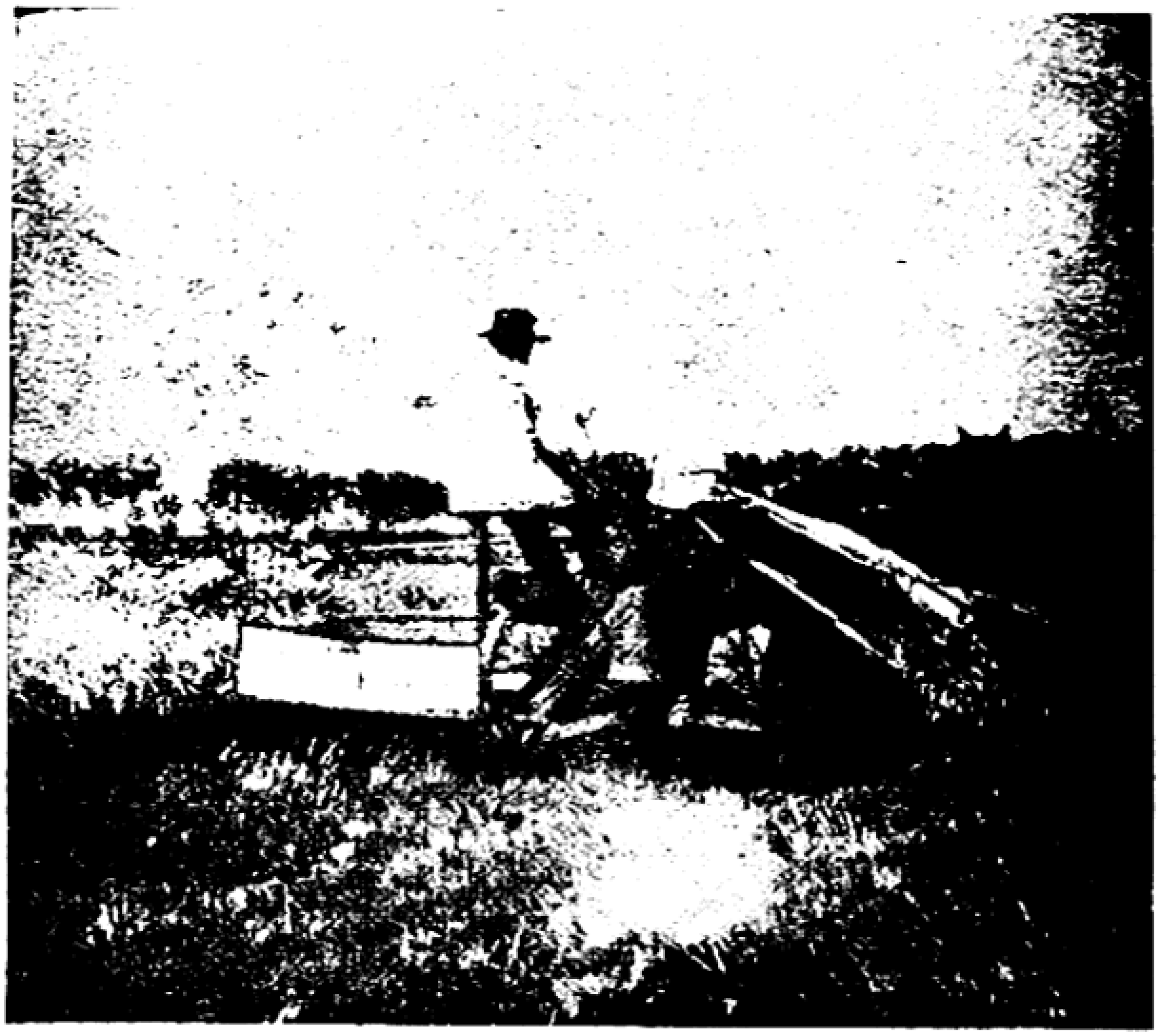
Nevertheless in view of the increasing scarcity and cost of labour and of the slowness of the work by manual labour, it will be a very desirable improvement if some kind of labour-saving appliance or machine can be successfully introduced. It is a far cry from the present primitive methods to the harvesting by giant machines now in use all over the U.S.A., Russia, Australia and other countries which cut ('head' or remove only the earheads, as a matter of fact), thresh, clean and bag the grain, all in one operation as they move along the field; anything approaching these in India can hardly be thought of. There is however scope for some of the smaller appliances, which were in use formerly in those countries but which have now gone into oblivion. These are (1) the Scythe and (2) the Reaping Machine.

1. *The Scythe.*—This is only a manual labour tool, but its capacity is very much greater than that of the sickle. The blade is about 3½′ in length, which is about three times the length of the sickle blade; the stalks of grain have no need to be held together by the hand and in the way in which it is wielded, it can cut a width or 'swath' of about 4′ or more at one sweep. The British labourer can harvest an acre or acre and a half of wheat in a day using a scythe and in the case of oats and barley almost double this extent. In actual working, a set of men accompany the scythemen, gathering and binding the sheaves cut by the scythes. As the tool is handled only by men, it can do the selective harvesting necessary in the case of mixed crops, but lodged grain will of course be difficult to manage. Unlike the sickle the scythe has to be used by the labourer in a standing posture. A certain amount of deftness is also required but this comes by practice. The trouble with the implement is its novelty and the method of working, to which the Indian labourer will not take. These probably account for the fact that though it has been introduced and tried here and there in India, it did not catch on; the saving in labour and time will be very material if it is used, and both are of urgent and growing importance.

2. *The Reaping Machine.*—This machine is probably the simplest which can be thought of for bullock draft. It is only a slight advance over the mowing machines which in recent years have come much into use for cutting grass on the Grass Farms in India and may not be therefore altogether a novelty. Two types are available, which differ only in the manner in which the cut swaths are gathered and removed out of the way. In one, the work is mechanical, a kind of sweep rake forms part of the machine and works as the machine moves along, so that both cutting the grain and gathering the sheaves are carried out by the machine at the same time. In the other type this self-raking arrangement is dispensed with, and the work is done by an extra workman who follows the machine gathering and raking away the cut swaths. A reaping machine



Circular Chaff Cutter, manufactured by Messrs. Kirloskar Bros.
By Courtesy of the Company



The self-binder, horse drawn machine, harvesting wheat.
Photo by Author

Scene showing the threshing of Jowar, by means of the Stone Threshing Roller. *Photo by Author*

capable of harvesting 10 acres of ragi per day and manufactured by Messrs. Massey Harris of Toronto, Canada, was tried on the Hebbal Farm, Bangalore, and did satisfactory work. There should of course be no mixed crop nor should the grain be badly lodged. The knife sections in the cutter bar have to be kept quite sharp and above all the machine has to travel at a particular speed, and good bullocks have to be used both on account of the heavy work and the speed required. Fields have also to be clean and free from stones, as otherwise the knife is damaged. Although the cutter bar can be adjusted for height to a certain extent, the stubble is generally left somewhat higher than usual and certainly more than to the ryots' liking. When however the very great saving in time and labour implied in the harvesting of some 10 acres a day with only a bullock implement is considered, the use of the machine, if at all possible, appears very desirable. Alterations for making it simpler and more suitable are not impossible and deserve close study. The cutter bar may be shortened and the gearing altered to suit bullocks and perhaps other adaptations also considered.

3. *The Self-binder.*—This is the most advanced among the types discarded in America. The machine cuts the grain, collects the cut stems, ties them up into sheaves of uniform size by means of twine, knots the twine and delivers the tied up bundles or sheaves at regular distances as the machine moves along. This is a much more complicated and heavy machine and is drawn by a pair of powerful horses or by a tractor. It may suit areas like the Panjab where wheat is grown over very large areas and in large holdings, but its use connotes a country much more advanced in the use of machinery than India is at present, both on account of the mechanical skill and technical knowledge required and the general facility for executing repairs and renewals. It will probably be the acme of perfection which India may look forward to in this matter.

Many important consequential changes will have to come in, before any satisfactory progress can be expected in the use of such labour-saving machinery in the present practices, which may take place perhaps *pari passu* with each other. Some of these have already been mentioned, *viz.*, the training in the use of tools worked in a standing posture, the growing of pure crops, the growing of stiff-strawed varieties and the breeding of types combining stiff straw with high yield, the harvesting of crops considerably in advance of the dead-ripe stage, a throwing together or consolidation of the fields or co-operative action and so on.

Threshing Methods and Machinery

Present Methods and Need for Speeding up

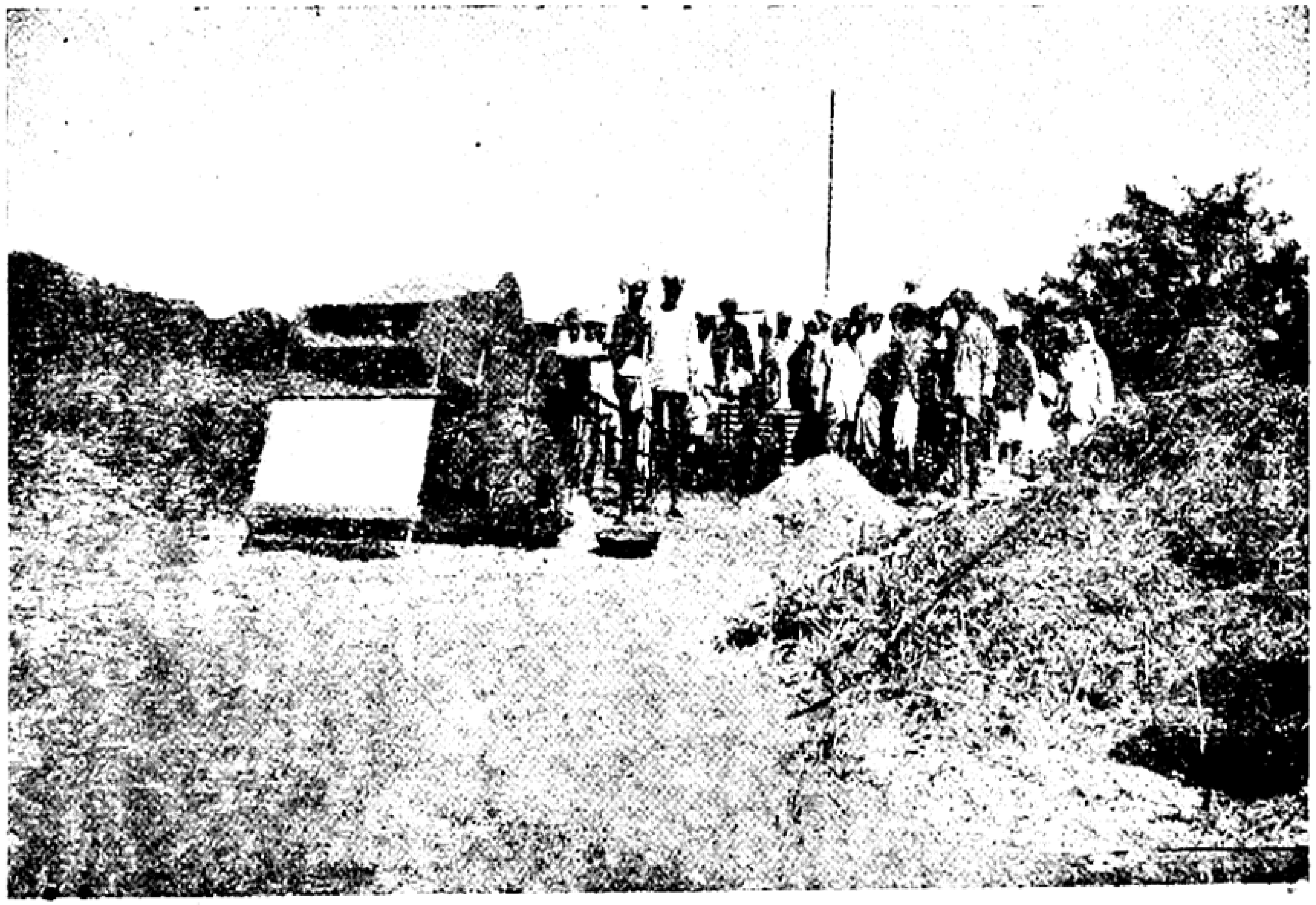
Grains and pulses of all kinds are threshed only by one or other of the following methods: (1) beating the earheads with sticks (or flails); (2) beating the sheaves against a board or slab of stone

(as in the case of rice); (3) trampling out the grain under the feet of oxen; and (4) working a stone roller or a set of smaller rollers over the earheads and separating the grain out. As regards saving in time and labour and practical convenience, these methods are in the ascending order of efficiency. The saving in time and labour which the last method effects has been so well appreciated that though the method is comparatively new, it is steadily replacing the others.

Although the season of threshing crops is a slack time as far as field operations are concerned and as a certain amount of leisurely work may be permitted, still it must be noted that this is not so in villages where both dry and wet cultivation may prevail and still more in villages where there is garden cultivation in addition. For, about this time many operations crowd in, *viz.*, milling of sugarcane, preparing the field for sugarcane, planting it, preparing rice fields for the hot weather crop of rice, autumn or post-harvest ploughing of the dry land fields themselves, digging or deep ploughing in black cotton soil fields and so on. The carting of produce to market has to be attended to at the correct time to take advantage of favourable prices, especially in the case of groundnuts and cotton which are very bulky and cannot be stored at home. Furthermore, winnowing forms part of the threshing operation and has to be carried out on the threshing floor itself and the grain has to be ready whenever a wind blows. All in all, the time or season during the threshing is a very busy one in such villages and a speeding up of the process is of great importance.

Stone Threshing Roller.—The stone threshing roller is a great improvement on the older method of beating out the grain by hand or treading it out under the feet of bullocks. The roller is about 3′ in length and 2′ in diameter and is mounted in an axle and frame like a tennis court roller. It is also fitted with a beam and yoke for hitching bullocks and a seat for the driver to sit on. Incidentally this may be said to be the only implement in Indian agriculture in which the operator rides. The roller is made generally quite cylindrical in shape but sometimes a slight difference is made between the diameter of one face and that of the other, so that it looks like a section of a truncated cone; even normally, after some years' use it assumes this shape by the uneven wear brought about by moving it round and round.

For actual working, the sheaves (or only the earheads in the case of jowar) are well dried and spread circularly in a thick layer, the roller is then driven over the layer round and round until the grains are separated out, the straw is then raked off and a further layer put in for threshing. Occasionally a second threshing of the unthreshed earheads in which some grains may be still left may have to be done. This will be the case when the sheaves were not sufficiently dry or the earheads are not quite mature. The roller is now



View of one of the village threshing demonstrations, referred to in the text, of threshing ragi by an outfit consisting of a small American Threshing machine and a portable oil engine. *Photo by Author*

being used for the threshing of all grain crops and for the pulse crops also to a steadily increasing extent.

Wheat Threshing Roller.—A somewhat similar principle is made use of in the wheat threshing roller of Gujarat. In this appliance, instead of one large roller, a number of small rollers work over the sheaves. These rollers are of the size of the discs in a disc harrow and a set of six is mounted on a single axle; three such sets are fixed in a square frame, the sets being placed one behind the other and parallel to each other, but the rollers are so mounted that no two rollers move in the same track. The roller frame is provided with a seat for the driver to sit on and the machine is worked over the sheaves in the same way as the stone threshing roller. For the threshing of wheat it is said to be a very efficient method.

Threshing Machines.—In foreign countries machines, both large and small, are used for threshing, which possess many mechanical details and have to be worked by engines or tractors. Occasionally the smaller outfits are worked by "sweep" power or bullock gear. These machines carry out the threshing by pulling the earheads between fast-moving teeth, somewhat like passing them between the teeth of a comb. The essential part of the machine consists therefore of this mechanism, which is provided by a large drum or cylinder on the periphery of which strong teeth either flat or conical in shape are fixed and by a hollow half-cylinder called 'concave', whose concave face is likewise provided with similar teeth. The drum revolves inside the concave, which is fixed and stationary, so that the teeth on the drum pass between the teeth on the concave very closely. The teeth in both are so fixed that though they come very near to each other they do not touch or get jammed. The sheaves are fed into the machine and are pulled through between the teeth of the revolving drum or cylinder and the teeth on the stationary concave and the grains are thereby separated from the heads. The setting of the teeth and even their shape has to be different for different grains and their adjustment also has to be altered suitably, so that the grains are separated out completely without there being any appreciable breakage. The threshed grain falls through a grate under the concave and the straw is passed forward out of the machine.

Other parts of the machine comprise (1) the straw shakers, which pass the straw forward to the opposite end and keep shaking it up at the same time to shake out the grain and chaff; (2) a blower or revolving fan which winnows the grain removing the chaff, dust, etc.; (3) a grating under the concave to pass the grain (and part of the chaff) through, from which they drop on; (4) receiving boards and sieves, which are also kept oscillating and separate out the chaff and foreign matter; (5) two or more spouts through which the clean grain and imperfectly threshed bits of earheads, heavier chaff, etc., flow out of the machine; and (6) an

elevator, also usually forms part of the machine, which raises the grain from the mouth of the spout higher up for bagging. The whole series of movements of the different parts are properly synchronised and are driven, off a single pulley which works the drum.

In Mysore for the threshing of ragi, small American threshing machines were got out and were found, after slight modifications, to suit this grain quite well. An American thresher called the "Little Giant" and manufactured by Messrs. Heebner and Sons of Londsdale, Penn., was found quite useful and some machines were got out for large land-holders and used with success. The Department of Agriculture also conducted demonstrations of the machine in the villages, a portable oil-engine and the machine being the unit taken from place to place and demonstrated. A certain amount of breakage of grain and some unthreshed earheads were the drawbacks, but after adjustments were made these were only negligible. It may be said that the ragi grain is rather difficult to thresh and perhaps most difficult among the grains and the machine is therefore a great help. The machine was also copied locally, but was subject to considerable damage owing to the rather violent vibrations and the warping and splitting of the wood-work. With selected wood it could be made more durable and should prove of real relief to both large growers and for co-operative work.

Winnowing Machines.—The ordinary method of winnowing grain is the familiar one of letting it down from a height when a good wind is blowing, which wafts the chaff and poor and light portions from the sound grain, which however will have to be passed through sieves later on for removing stones and other heavy foreign matter. The process is slow and is not quite free from risk to the labourer who has to stand on a tall narrow bench or perch himself on this rather uncertain footing and minding both the grain and his own self. The process is slow, and one has to wait for and take advantage of a good wind, when alone the work can be carried out. The work moreover can be done only out in the open. Small winnowing machines can be used instead which can be operated whenever wanted whether a wind is blowing or not, and can be worked indoors in any weather. The machines not only winnow the grain but also put it through one or more screens, when it is cleaned from admixture of gravel, mud and dust and even graded to some extent. There are many small units fit for manual power in use and probably the ordinary winnowing machine may be said to be the machine most in use, as far as the use of agricultural machinery goes in India.

Their essential parts are only a revolving fan for producing a powerful blast, and a set of oscillating frames containing screens of different mesh. The grain is poured through a hopper and in passing down over or through the different screens or sieves is subjected to the action of the blast which blows away the lighter particles. The clean grain flows out through a spout, the chaff and other light portions are blown off in the blast and the dust and earth fall under

the machine. The small machines are very handy, being the size of an ordinary writing table, and can be worked by the hand by turning a crank, the revolution of the fan and the oscillation of the screens going on simultaneously. Many manufacturers of agricultural implements in India are now making these machines and several sizes are available for manual power or motors.

Feed Cutting Machines

One of the means of economising fodder, whether green or dry, which applies particularly to jowar fodder, is by cutting it into small pieces or 'chaffing' it, and feeding it either by itself or mixed with concentrated feeds like horsegram, oil-cake, cotton-seed, etc. In the case of jowar green fodder it is a common practice in many parts of Mysore to cram it into the mouths of animals until the whole of it is eaten from the leafy tops to the comparatively hard and coarse root end of the stems, and thereby to see that nothing is wasted. In the case of dry stalks of jowar it is cut into two or more pieces and in addition is sometimes softened by soaking in water before feeding it. Even then, large quantities are wasted. All kinds of long stemmed fodder like straw, green sunnhemp, etc., can be greatly economised if cut into small bits. More than one type of indigenous cutter can be seen, in which the cutting is done by means of a heavy bladed knife with a long handle which is hinged at one end and works nut-cracker fashion. In others the blade is curved like a sickle, and the sheaves are cut by pressing both ends with the feet and drawing the blade of the knife from below the sheaf out through it. This is both difficult and slow and requires much strength of arm.

A better type which is largely coming into use is one in which the blade is slightly curved and is fastened to a revolving wheel which moves close to a horizontal narrow platform; the fodder moves over this platform and is cut into bits as it is pushed under the blade. The machine is made in many sizes and the most popular ones are hand operated and are small and cheap enough for individual farmers or cattle owners and tonga horse owners in cities. The machine has an adjustment for cutting the bits short or long. In machines which are intended to be driven by power, there is a self-feeding arrangement, which dispenses with the need for pushing the fodder into the machine by hand. In still larger machines intended for use in connection with silo towers, there is also a powerful fan which blows the chaffed fodder through large pipes into the silo, dispensing with the need for men to carry it up along ladders. The small hand-operated machines of this kind which are now largely in use in Upper India deserve to be taken up in other parts of India also. Smooth and soft straws like ragi are too yielding and the cutting is not thorough. Fodder should be well shaken before feeding into the machine to remove little pebbles or hard substances which may injure the blade.

Other Feed Preparing Machines

Feed grinders for cracking or 'kibbling' grains, pulses and cotton-seed also effect considerable economy in feeding, and for large farmers will be found more efficient and labour-saving than their present household methods. Cake crushers for breaking oilcakes into small lumps and root slicing machines for slicing mangolds, turnips, swedes are machines very common in farms in foreign countries, which turn out more work than the simple one of cutting or breaking them with knives or mallets.

It is well to bear in mind as a general principle in regard to the need for and use of labour-saving or improved tools and appliances, that the economy arises not only from the large capacity of a machine but also from the relief it affords to the labourer from physical strain and positive discomfort or pain to which he gets accustomed and resigned, but all of which seriously diminish his capacity and efficiency. Apart therefore from the humanitarian considerations which may not always appeal to the employer of labour, from the purely economic point of view of increased efficiency also, labour-saving or improved appliances deserve introduction, even in agriculture in which considerable human labour involving physical strain cannot altogether be dispensed with.

Machines for Preparing Produce

Many operations involved in the preparation or finishing of produce either for the home or for sale, which used to be carried out in small domestic appliances have in recent years passed out of the farm and are now conducted on a large scale in centralised concerns, where the requisite machinery is installed in small or large units and worked by electric motors or oil or steam engines. These are, for example, (1) ginning of cotton, (2) the hulling of rice, (3) grinding of flour, (4) hulling of groundnuts. The countryside is studded with establishments for all these processes, each according to the crop region concerned. In the case of flour milling, every city, town, and fair-sized village now possesses power-driven flour mills, where the various grains are ground for customers at a very cheap rate and quickly almost on a while-you-wait basis and these have banished the domestic drudgery which formed part of the daily task of the womenfolk at home.

Sugarcane Milling

The only notable operation in this class which still remains as a farm operation involving the use of some mechanical appliances is the crushing of sugarcane. With the advent of the large sugar manufacturing concerns in India, which produce direct consumption sugar and therefore handle the sugarcane crop themselves, the importance of milling on the farm has very much dwindled; but the cultivation of sugarcane in isolated places and far away from sugar

factories is still very extensive in the aggregate and farm milling of cane must remain a permanent feature in India. Sugarcane crushing mills therefore constitute the only kind of machinery that need be dealt with in this connection.

Early Mills.—Until about fifty or sixty years ago, only wooden mills were in use all over India for the crushing of sugarcane. These were of two distinct types, *viz.*, (1) a roller type somewhat similar to the present-day iron mills in which the canes were crushed between two rollers (or three in some) set tight against each other; (2) a less familiar type similar to the local oil mills (or *ganas*) in which the cane cut into small bits was ground up and the juice squeezed out in the process.

Wooden Roller Mill.—The roller type of mill had either two rollers or three rollers, set vertically side by side in a straight line; they were about 3½′ to 4′ in height and about 10″ in diameter. At the top they were cut into the shape of an endless screw, the massive threads of one engaged and meshed with the corresponding spiral groove in the other. One of the rollers was the power or drive roller, which was turned by a pair of bullocks in the same manner as the present iron mills and it set the others in motion. Canes were crushed twice and even thrice and, as only soft canes were grown in those days, the extraction was fairly good. The capacity of one such mill was found to be 2 cwt. per hour and the extraction 57%, as against a capacity of 456 lb. of cane per hour with an extraction of 68% given by an iron three roller mill of size 10′ by 8″ which was worked side by side in a comparative test. The difference of 11% in the extraction will mean something like 500 lb. of jaggery on even a moderate crop of 20 tons of cane per acre. Both the two wooden types of mills have now become quite obsolete and cannot be met with even as a curiosity except perhaps the huge rollers which are sometimes stowed away as lumber in old family houses in remote villages.

Iron Mills.—These comprise bullock mills and power-driven mills of the three roller type. Power-driven mills installed in factories are all multiple mills, consisting of three or four sets of three rollers each, and also provided with a set of crushers (of two rollers) in addition which prepare the cane for the rollers proper. Canes are broken or split in the crushers and passed through successively from one mill into the next, so that crushing takes place in each of the three or four sets of roller mills. The crushed cane is also 'macerated' or sprinkled with water after passing through the first set of rollers and again successively between the further crushings. All these are giant mills with rollers usually 6′ in length, requiring correspondingly high power, generally furnished by steam engines, and they form the sugarcane crushing part of the factories. A description of these mills does not come within the scope of this book.

The Three-Roller Iron Bullock Mills.—These are composed of three rollers usually 10" × 8", one of the rollers being of a smaller diameter than the two others. They are fixed vertically in a triangular setting and close together. To the top central shaft of the rollers are fitted cog wheels which engage each other and transmit the motion from the drive wheel to the other two. The drive roller carries a head piece to which a long horizontal beam can be bolted or fastened at one of its ends, the other end being used for a yoke and the hitching of bullocks. All the rollers are slightly grooved on the outer face and this helps in gripping the cane better. All rollers, when fixed ready for use are set very close, the space between the drive roller and the feed roller is slightly more than the space between the drive roller and the crushing roller, between which only the blade of pen knife can just pass. The cane is passed between the drive and feed rollers first and then between the drive roller and the crushing roller, automatically. The bed plate has three depressions for the lower ends of the shafts of the three rollers, in which they stand loosely and upon iron washers provided for the purpose; in addition the bed plate has a long spout through which the juice flows out into a collecting receptacle. The top plate has also similar housing for the top ends of the shafts, an arrangement for tightening and slackening the roller and for oiling the bearings. The mill is provided with three legs of iron to which the base can be bolted, alternatively wooden legs can also be used instead of the iron legs. These are fixed firmly in the ground and form the fixed foundation of the mill. Care has to be taken to see that the mill stands perfectly level and the rollers quite vertical, and though the former is attended to only when fixing the mill the latter may require looking into now and then. Roller surfaces of the drive roller and the crushing roller and the cog wheels are all subject to wear and the former will wear quite smooth after some years and will have to be regrooved. Canes may be fed either whole or in cut lengths, when they are crooked. The bagasse or crushed refuse will have to be examined now and again to see if the crushing is normal and if not, the mill will have to be tightened. Frequent oiling is necessary and the feeding should be adjusted to the strength of the bullocks, not more than two canes being fed at a time except rarely. Any adhering bagasse or cane not turning into the crushing roller should not be scraped or touched when the mill is in motion but the bullocks should be stopped until this is attended to.

Mills greatly differ in the ease of their working and in the extraction they give. From 5% to 10% of difference in extraction may be found between an ordinary mill and the better class of mills. The draft in these mills (in certain comparative tests) varied from 105 lb. to 165 lb. feeding three canes at a time and when four canes were fed in the latter mill the draft rose to 205 lb. The weight of canes milled per hour when three canes were fed was 325 lb. and when four canes were fed 400 lb. The draft will no doubt increase

with the hardness of the cane. Practically all the new varieties of cane (seedling canes) now being grown in India are hard rinded, while the older canes are soft rinded. In fact, when these new canes were being introduced and only a few growers were growing them the others would not spare their bullocks for milling these new canes, as it was difficult work.

The drive is usually with one pair of bullocks; but in some tracts a kind of double beam is used, the total length fully equal to the diameter of the sweep and one pair is attached to either of the two ends. This of course reduces the strain on each pair to one half. At the end of each day's work, the mill has to be thoroughly washed with hot water (or boiling water) and well cleaned, so that juice or bagasse does not lodge in the depressions or other parts and ferment; this will be harmful to the fresh juice when milling is resumed later on. Thorough and frequent oiling and cleaning the oil hole to see that oil passes through without impediment are quite necessary as well as a general tightening up and prevention of lost motion and shaking or creaking.

In some models these bullock mills may be fitted with gear for belt drive from a motor or engine; but unless exceptionally well designed they are not satisfactory, they work too fast and the gears heat up inordinately.

The Three-Roller Power Mill.—As already stated, we shall consider only the small-scale mill, which consists of only one set of rollers and is suitable for individual ownership by a large grower or a small co-operative society formed for the purpose. All these mills are horizontal mills, in contrast with the bullock mills which are vertical.

The considerations mentioned in favour of using threshing appliances which will greatly reduce the time taken and set free cultivators for other and equally important work apply with even greater force to the speeding up of cane-milling operations in the villages. This can be done only by the installation of power-driven mills. Even a small horizontal mill of 18″ × 12″ rollers will crush about a ton of cane per hour; this is a quantity which will require at least six hours of continuous milling with a good bullock mill. In other words as far as milling goes, the work can be finished in a sixth of the time taken by a bullock mill. It cannot be said that the difficulty can be got over by installing a number of bullock-driven mills, as the labour available in men and bullocks is not large enough for this purpose and generally puts an inexorable limit to the mills that can be installed and worked. Such a small power mill will require only a 5 or 6 H.P. engine to work it satisfactorily.

The power mill has other important advantages besides the larger capacity, *viz.,* (1) a higher extraction, and (2) ability to crush the hard rinded superior canes better. The extraction may go up to about 75% as a maximum which is a very large gain, especially in the case of those who grow a heavy tonnage of cane.

The ability to crush the superior canes is a great point in its favour, as all the high-yielding new varieties of cane are hard rinded and cannot be crushed in bullock mills without a heavy strain on the bullocks and even then, not efficiently in extraction. The full advantage of growing these canes can be derived only by the use of power mills.

The installation of power mills will necessitate provision for handling the juice and boiling it down into jaggery expeditiously. Some six boiling pans will have to be set up for the purpose, the boiling being done either over single furnaces or multiple furnaces. Whichever method is adopted boiling should be rapid and efficient and should cope with the juice as it comes in without the need for keeping it for any length of time.

Jaggery Boiling House Appliances

In the jaggery boiling house itself, many small appliances and methods can be improved with advantage; the use of a pulley and chain for hoisting or tilting the pan, the use of a knock-down detachable type of mould for pouring in the charge for the final setting, good metallic sieves with wiregauze for the ladles used for the removal of scum in the place of the crude wicker baskets now used, are examples.

Areca Shelling and Curing

In the arecanut-growing districts, a very slow and laborious operation is that of shelling and slicing the nuts, preparatory to boiling the cut pieces. The work keeps all the members of the family engaged day and night, in spite of gangs of temporary labourers who trek to these villages during the season. Both shelling and slicing are carried out as part of one operation, but the former is the one which is more laborious and would be greatly facilitated if it can be replaced by machinery. Quickness of work is very necessary as the nuts have to be at the correct stage of ripeness for ensuring good quality and the use of machinery will be found very helpful. A few attempts have been made here and there but the operation seems to be one in which human labour cannot be displaced; at any rate none of the attempts have been even a partial success. Here is a field for the exercise of an inventor's talent.

Areca Drier

An improved appliance in this connection is the artificial drier. The areca slices or whole nuts after boiling have to be dried thoroughly and seven days of good sunshine are generally reckoned as necessary for the purpose. In the malnad arecanut tracts, from where the best qualities are supplied, the early harvests come at a time when the rains have not quite ceased; depending solely upon sunshine at this time is a risky proceeding. A crude form of drying over a low burning wood fire is resorted to but this is very unsatis-

factory in many ways, notably in lowering the quality of cured nuts and also in the attendant risk of fire. An artificial drier called the "Chula" was imported and installed on the Marthur Farm by the Mysore Department of Agriculture and was found quite useful. It is capable of being constructed of local materials and was as a matter of fact copied by some of the garden owners in that neighbourhood.

Some Minor Appliances

There are many small mechanical devices which can be used with advantage both for easing the labour of men and of speeding up work in the daily tasks on the farm but the general instinct is to use one's hands and back rather than a machine. For example, although the hoisting of materials is a daily operation whether it be produce for drying on overhead platforms 20′ high or for storage in a loft or upper storey, it is carried laboriously up a ladder though it can be done with greater ease by means of a pulley and rope. Similarly heavy bags of grain and other heavy material in bags are shifted by carrying them on the back rather than by a wheeled sled or barrow. Many small machines suited to Indian conditions await study with a view to the saving of time and labour, such as for example, harvesting groundnuts, threshing of grains, extraction of fibres, plaiting of ropes, sowing of seeds and so on. Machines in use on farms on the continent of Europe may perhaps afford models which may be found more suitable for adaptation to conditions in India than British or American models, as the former are generally small types designed for comparatively smaller holdings.

Farm Carts

Main Features

Bullocks are the draft animals of India and all manner of carting whether on roads for transport of goods and passenger traffic or on the farm for carting manure and produce is carried on in bullock-drawn carts. Much comment has been made on the imperfections of the bullock carts as a vehicle and improvements suggested which have a twofold object, *viz.,* firstly, in the interest of the cart itself and its efficiency and secondly, in the interest of the roads in the country. Before considering in what ways improvements are called for or possible, some of the characteristics of the ordinary bullock cart may be mentioned :—

1. They are all of the two-wheel type, and, barring special vehicles for heavy road transport in cities drawn by large heavy bullocks somewhat like the horse-drawn brewers' drays in England which are low and four-wheeled, all Indian carts may be said to belong to the two-wheeled type. This feature strictly limits the size of the frame and capacity (the floor area) of the cart and has also a bearing upon the stability of the cart when laden with bulky goods like straw, cotton bales, sheaves of grain from the fields, etc.

2. The axle which is of iron is a single rod (square in section and round and slightly tapering at the ends) and is fixed and rigid; the wheels revolve over the ends of the axle and are kept in from slipping or moving out of alignment by means of axle pins. The hole in the hub for passing the axle through is faced with an iron bush of fixed bearing on which the axle rests and turns. The wheel is fitted somewhat loosely over the axle, so that there is always considerable play and a slight wobbling or movement of the wheel in and out now hitting against the axle tree and now hitting against the axle pin itself. The two ends of the axle are open and not covered or protected against dust.

3. Wheels vary in height and form. The usual height in Mysore is 4′ 10″; carts however can be seen in South India with wheels very much higher. Smaller wheels about two-thirds of this height are also common, especially in carts used for driving like buggies. More than one type in this respect can be seen, which depends upon the breed or type of bullocks common in the tract, the smaller the type the lower is the wheel. Some of these low-wheeled carts are sprung, but this is exceptional and is confined to certain districts and to pleasure carts alone.

Wheels are of the ordinary open spoke and felloe type and are set in a vertical plane and there is no dished shape attempted. In special cases wheels are solid, but these are low, only about 2′ in height looking like disc wheels. They are used almost like sleds on country tracks, or over fields, in forest country over rocky and all manner of ground and are to be found only in remote villages. In some villages there are special solid wheel carts which are quite 4½′ in height with massive iron tyres about an inch or more in thickness. These are used for hauling jowar stalks from the harvested field, the frame of the cart is widened for holding a large load, and the cart is drawn by three or four pairs of bullocks. Such solid wheels are of course much stronger than the open spoke and felloe type and are fit for the rough work and country on which they are used.

The tread or width of the tyre is generally uniform and is 2″ wide and 2/3″ thick (in South India). Wider wheels can be seen however in Upper India, where the soft alluvial roads (or no roads) require such width.

4. Friction in the axle is reduced by a lubricant made by rubbing up fine carbon (got by burning straw) with castor oil. Both ends of the axle and the facing or bush in the hub wear smooth gradually, which added to the lubricant further reduces the friction. The wheel has to be slipped off and on every time the lubricant is applied. There is considerable creaking and shaking of the wheels nevertheless which tends to add to the strain.

5. Slow and creaking as the motion is, carts in many parts of Mysore where the roads are fairly steep and in the ghaut country invariably have to be provided with *brakes*. This is a simple and

clever device, two blocks of wood (or one long piece serving both wheels) are loosely slung behind and close to the wheels and are tied to a long string or length of cane which reaches the front just below the driver's feet. Pressing this end down with the feet the driver brings the brake block to bear upon the wheels, as tightly as may be desired, and so to make them slow down the motion; the brake blocks wear out very soon, but as any odd piece of jungle wood will do for the purpose this is no serious matter.

6. The hitch is quite rigid; a yoke is tied to the pole or shaft which forms the middle piece part of the frame and about 15′ in length and at about 5′ from the driver's seat so that the bullocks are very near to the driver. As there are no traces or chains and as yoking or hitching is a rigid arrangement, the strain on the bullocks is very great on steep roads; on the up grade the yoke tends to lift up and on the down grade it tends to dip and bear hard on the neck of the animals, making the draft difficult in both cases.

Draft of Carts

The general principles governing the draft or strain involved in haulage in country carts may now be briefly dealt with. The factors which contribute to the draft relate to (*a*) the road, *i.e.*, both the gradient and the surface; (*b*) the load; and (*c*) the cart *itself*, *i.e.*, its parts and manner of construction. It is with the last factor that we are concerned in this connection, but a word may be said about the other two factors also.

(*a*) *Draft and Road Surface.*—The gradient of the road is the largest factor involved in the draft; the steeper the slope the heavier is the draft or the less the load that can be carried than on a level road. The gradients of the roads in the country set a limit to the capacity and size of carts, as do of course the size of the bullocks used. A steady pull over a long stretch of steep road is a most taxing strain on the bullocks and in the pre-motor days roads used to be remade or realigned periodically with the object of easing the grades though increasing of course the length of haulage. Roads designed for motor traffic and bullock cart traffic at the same time sacrifice the interests of the latter to the former.

(*b*) *Draft and Load.*—Draft is of course directly proportional to the load. As the load which can be drawn has to be limited to the capacity of the average pair of bullocks, the present capacity of the cart cannot be materially enlarged by making a larger frame, or furnishing four wheels and such other methods.

(*c*) *Draft as affected by the Cart*—(1) *Height of Wheel.*—As far as the cart is concerned, the draft varies with the height of the wheel, the width of the wheel and with the axle friction. The higher the wheel, the lower is the draft and *vice versa*. Practical considerations influencing this factor are the additional difficulty in loading such tall carts, the larger size of bullocks needed and the extra instability of the cart when loaded high with bulky materials.

A medium height such as is the case with the Mysore cart is perhaps a good compromise.

(2) *Width of Wheel Tread or Tyre.*—Within limits, the wider the tyre the less the draft and the less the damage to the roads. The advantage of a wide tyre becomes very striking as the road surface becomes soft as in the case of mere earthen tracks, pasture land or stubble fields. American experiments quoted by Prof. F. H. King, show that wide tyres reduced the draft from 17% to 120%, on stubble or pasture land, 52% to 61% on clay roads with deep mud, by 27% on smooth roads, 24% on gravel roads, and 26% on metalled roads (macadam). If however the mud is sticky as in the case of clay or the black cotton soil and clings to the wheels in large lumps, the narrow type scores over the wide tyre. Although in Europe the permissible width of tyres is prescribed by Governments in the interests of the roads and tyres up to 6" in width have to be used when heavy loads are carted, it is doubtful if in India the loads which can be drawn by an ordinary pair of cart bullocks will necessitate any wider widths than are to be seen at present.

Rubber Tyres (Pneumatic) for Farm Carts.—Within the last few years it has been suggested that pneumatic rubber tyres similar to those on automobiles may be used on farm carts also, and cart wheels suited to the purpose have been designed and used, and also recommended. This is for two reasons, *viz.,* (1) the protection of the road surface, and (2) the easing of the strain on the bullocks. As regards the first the present steel tyre seems to be anathema to engineers who condemn it unreservedly; thus "it is the steel tyre that (if allowed to persist) will throttle the development of agriculture, education and whatever goes to make a nation great"—says an Engineer. As regards the second, some comparative tests of the draft in these carts as against the ordinary ones have also been conducted, which show that much larger loads (at least double) are possible with the rubber tyre than with the ordinary wheels on farm roads. This of course is only to be expected, but it seems doubtful if the introduction of such wheels can be considered practicable although it is very desirable. The high cost of the cart and the new wheels, the liability to damage and need for repairs which cannot be attended to by the ordinary villager and the need for effective brakes in steep country will, in practice, render its use very limited. On the other hand, larger capacities and loads are possible with the same type of bullocks, or for the same load as at present, a single bullock or a smaller pair may be enough. From the point of view of saving to the road surface, they have undoubted advantage. If the difficulties pointed out above are suitably overcome, the usefulness of such rubber tyred carts may increase materially.

Roller Bearings.—Another improvement thought of is the provision of roller bearings for the axle inside the hub instead of the fixed bushing. This would appear a desirable one, as the friction in the present wheels is very great; the addition of such bearings

looks also simple as it does not involve any great change in the construction of the cart. At the same time it must be remembered that axle friction as a factor in the draft forms a very minor one as compared with the others. Moreover in the ghaut country and even where roads are even only moderately steep, the need for effective brakes will assume greater importance and it is doubtful if the present crude brakes will answer. Even as it is, on such roads the brakes have to be kept pressed hard continuously on the wheel face, creating a screeching which those who have travelled on such roads will never forget. Brakes will have to be of better material and even in town roads they cannot be dispensed with. It is not known if many carts were at any time fitted with such bearings and what the experience has been.

Yokes.—Bullocks are hitched for work in India by means of the yoke, which rests and bears upon their necks, from which part of the body the power is applied. The characteristic hump of the Indian or Zebu cattle is favourable for this sort of attachment, so much so that the male progeny of cross-bred cows, which are humpless are not deemed useful for draft purposes and fetch a very low price as compared with the Zebu humped male stock. There are many different variations in the shape of the yoke and its attendant features for keeping it in position and each kind is considered the best in the tract where it may be in general use.

The differences are to be seen in (1) the shape, *i.e.,* whether straight or curved; (2) in being single or double; (3) in the method by which it is kept in position, whether by straps, wooden pins or otherwise without allowing the animal to slip away; and (4) in the material of which they are made. All these have some bearing upon the effectiveness of the application of the power and upon the freedom from yoke gall or other injury to the neck of the animal.

In regard to shape, yokes are either one straight bar of wood cylindrical all the way or at least at the two ends where they lie on the neck of the animal or the ends are curved more or less (which gives rise to many types), so that the concavity conforms to some extent to the shape of the neck. Presumably at least the latter ought to be more easy on the animal, though it must be added that for all cart work the yoke is always of the straight type. Yokes may be single or double. Whether single or double the yoke bar which rests on the neck of the animal is either straight or curved. In the double yoke another straight bar is attached below and parallel to the top one and forming a kind of rectangular frame and fixed to the top yoke by four short rods or stout wooden pins, two for each animal which also serves to lock or confine the animals' neck in. It may be supposed that in this type the efficiency may be greater because the animal is able to exert power both from the neck and from above the chest, so that the pull may be more effective. In fact it is considered so by cultivators who use the method. On the

other hand in some rather elaborate tests of many kinds of yokes (at the Allahabad Agricultural Institute recently) this double yoke was not found to be superior. Out of four types which were classed as better than the others, three were single yokes and only one was a double yoke, and even this was not the regular type but somewhat intermediate. The same tests also showed that yokes with a pronounced curve over the neck of the animal were not superior to the straight yokes, although a slight curving or concavity appeared however to be an advantage. Of the four types adjudged best only one was a smooth and straight type, the three others were of the slightly curved types (see M. Vaugh in *Ind. Farming,* Vol. VI, No. 12).

Yokes have also to be judged by their freedom from liability to cause yoke galls. Practical farmers rely much upon the kind of wood used for this purpose and have particular preferences in this respect. The merit of the wood preferred is probably due to the absence of any special resin or gum or oil or other constituent likely to injure the skin and also to structural features like hard, soft, coarse or close grain, etc. Metallic rods are strictly avoided. In regard to shape the curved type is recommended as against straight type and of these the double is preferred to the single (see C. M. Mushtaq Ahmed in *Ind. Farming,* Vol. V, No. 4). The matter has apparently not been studied from both points of view at the same time.

CHAPTER XXII

THE USE OF THE TRACTOR IN AGRICULTURE

A. Ploughing and Other Tillage Operations

The use of the tracor for agricultural operations and the scope for the same in India have been much debated and a brief discussion of the question may not be out of place. Some aspects of the question, especially the subject of tractor ploughing, have already been dealt with (*vide* Chapter IX). The scope for tillage with tractors and tractor-drawn implements may be said to lie mainly in three directions, *viz.,* (1) for clearing of scrub jungle or waste land to be newly brought under cultivation; (2) for the ploughing and other tillage of land already under cultivation; (3) for the hot weather deep ploughing of the black cotton soil. Both (1) and (3) may be said to be of a special character; and the first only for meeting a temporary need. It is only in the case of (2) that the scope will be both wide and may fit into the general rural economy as a permanent feature, if it can be found suitable as it is, or made suitable after necessary adaptations.

1. Where large areas of new land have to be cleared, levelled and otherwise rendered suitable for cultivation, the use of tractors and tractor-drawn implements, especially a bull-dozer, will be found invaluable. As a great extension in cultivation is being planned in India and as many extensive stretches of jungle will have to be cleared or highly eroded land filled up and levelled, or 'kans' infested land broken up and made fit for cultivation, there is likely to be great scope for some years to come for this class of work. Carrying out such work by human or bullock labour is in practice quite out of the question, not only on account of the scarcity and cost of labour and the difficulty of moving and looking after large gangs in far-off jungle tracts, but also of the inherent difficulty of the work and the time it will take. The author had the privilege of securing the services of a bull-dozer outfit to work in clearing jungle on a large cattle salvage farm near Bangalore and can speak with much lively appreciation of the quality of the work turned out. Man-high thorny bushes were uprooted, and so were even trees of moderate size which were carried bodily away and deposited on the outskirts; boulders, both large and small, were picked up and moved as if they were pebbles and the land which was an impenetrable and boulder-strewn jungle was cleared so thoroughly and well, that it was possible to disc the land and sow fodder jowar very soon after. All this work involved as far as human agency actually on the job was concerned only a couple of sepoys. In reclaiming the vast areas of badly eroded land, comprising great stretches of the Indo-Gangetic alluvium in Upper India, the scope for these bull-dozers is very great. Large stretches of fertile waste land, overgrown

with deep-rooted 'kans' and grasses and very difficult to plough up with bullock implements can be advantageously and expeditiously broken up, cleaned and made fit for cultivation by the use of tractor-drawn ploughs. It will be advisable and profitable for the Governments of the different provinces concerned, to possess a sufficient number of these outfits, together with the necessary repair and renewal facilities for clearing land of these types for cultivation.

A point worth remembering in regard to Indian agricultural labour is that it is exceedingly immobile; families will put up with immense hardship if they can remain in their own villages or neighbourhoods rather than move out to far-off places, even though land ready for cultivation with irrigation facilities may be provided. To make them move to places where the land itself has to be cleared will be next to impossible. The preliminary work of making the land suitable for cultivation must be done by other agencies and the bull-dozer-*cum*-tractor outfits will prove most serviceable, if not indispensable.

Sometimes an equally powerful implement called a "brush-breaker" may be found useful; in fact before the bull-dozers came in and the gigantic land clearing work which they could do in a surprisingly short period of time came before the public eye during the last war, the 'brush-breaker' has been used in a few places for work of a somewhat similar character. It will plough up and uproot bushes and stumps but will not move them out of the way, nor as far as the author has seen can it cope with bushes or trees of the size that a bull-dozer can. It has however the advantage that it leaves the land in a ploughed condition. The uprooted bushes and scrub will have to be removed by manual labour. After the advent of the bull-dozers it is doubtful if the "brush-breaker" will have any scope worth considering, except where bush growth may be sparse and ploughing may be found an additional advantage.

2. *Scope for Tractor Work on Land already Under Cultivation.*—This is twofold, *viz.*, (*a*) the deep ploughing during the hot weather of black cotton soil fields, and (*b*) normal ploughing and other tillage operations on ordinary land as a regular yearly or seasonal operation.

(*a*) *Hot Weather Ploughing on Black Cotton Soil Fields.*—This matter has been fully dealt with already (*vide* Chapter IX). It may be added here that the work will have to be carried out only by machinery as time goes on and the present methods of using a large team of bullocks and men to plough with heavy ploughs or the digging of the fields will both go out of use before long and it will be necessary to provide for a good and efficient tractor ploughing service for this purpose, subject to what has been said already about the need for high-powered tractors and the facilities for prompt repairs and renewals.

The black cotton soil tracts in this country are not of equal importance in all parts of India. North of the Vindhya mountains

and of the Malwa plateau the areas are comparatively negligible and the scope therefore is very little. It is in the Deccan, in Bombay, the C.P., Hyderabad, Madras and Mysore that it will assume great importance. Another consideration which lessens the scope is the fact that the hot weather deep ploughing is required only once in about five years which is tantamount to reducing the area to one-fifth. Even when such allowances are made, tractor ploughing for this class of work will increase in importance and is likely to afford permanent scope for this type of agricultural machinery in India, whether it is owned by Government, by the large farmer or by any custom ploughing contractor.

(*b*) *Tractor Ploughing for Ordinary Soils.*—In regard to the question of tractor ploughing on the ordinary soils as part of the yearly operations, there is no doubt that the speeding up of the ploughing which is one of the chief merits of tractor ploughing will be found of great advantage. At present owing to the slowness of the ploughing with bullock power, only a small portion of one's holding is ploughed at the right time, and even that is not as thorough as the farmer would desire; much land remains left over for a later rain and for a hurried insufficient ploughing. The use of tractor ploughs will remedy this situation and this one important factor of crop production, *viz.*, thorough and timely ploughing can be vouchsafed for all the area to be cropped. The quality of the ploughing will also be more satisfactory as a general rule, great depth, thorough turning over and uniformity will be the result, all of which can be reasonably expected to increase the yield.

The ploughing of the ordinary soils with tractor ploughs is a very much easier and quicker operation; the tillage is shallower and the difficulties, strain, expense, liability to breakdowns, etc., are all far less than those with which tractor ploughing is now associated in one's mind. A ploughing of about 5″ is all that is necessary, even a smaller depth of 4″ not being ruled out. On a soil well softened after a good shower of rain this should be considered very quick work for any ordinary tractor and three or four 12″ plough bottoms can be worked by a tractor of moderate power. Often it may be possible to attain the 5″ depth with even a heavy disc harrow if the soil has enough moisture. With all the red loams quick and easy work is possible and with the light alluvial soils of Upper India the work should be easier and quicker still.

Terraced fields, small and scattered plots and the fragmented holdings are no doubt impediments. Where land is laid into numerous terraces as in the cultivation of rice and divided by innumerable low bunds even in level country, tractor ploughing is obviously out of the question. In respect of the other features, however, the difficulties can be easily got over with some amount of co-operation among the owners of the fields; the matter is one mainly of organisation, as explained below.

As regards cost of ploughing, although figures are available for such work during the tractor trials of pre-war days these are not applicable to present conditions, firstly because the ploughing in those trials was not the light ploughing referred to in this connection but the somewhat deeper and more difficult kind and secondly, the cost figures relating to labour, materials and the outfit itself are totally different from those prevailing at present. Reference may be made to at least the quantity of oil (fuel) consumed in the trials. During the trials of 1936-37, even the very heavy and high-powered tractors were found to consume only small quantities. Thus the W.D. 40 Mac Cormick Deering crude oil tractor consumed only 1·84 to 1·95 gallons per hour and a Hanomag 55 H.P. crude oil tractor consumed only 1·85 gallons per hour during these trials. In very extended trials during the years 1930-47 at the Lord Wandsworth College in Great Britain the T.V.O. consumption per hour of working was as follows (in the case of four tractors):—

Hours	Oil consumption per hour in gallons	Hours	Oil consumption per hour in gallons
650	1·21	1666	·94
1125	1·25	2040	·88

It will not be much wide of the mark if on the average it is reckoned that an acre can be ploughed (ordinary ploughing) with a consumption of half a gallon of crude oil, which in respect of cost must be considered low enough.

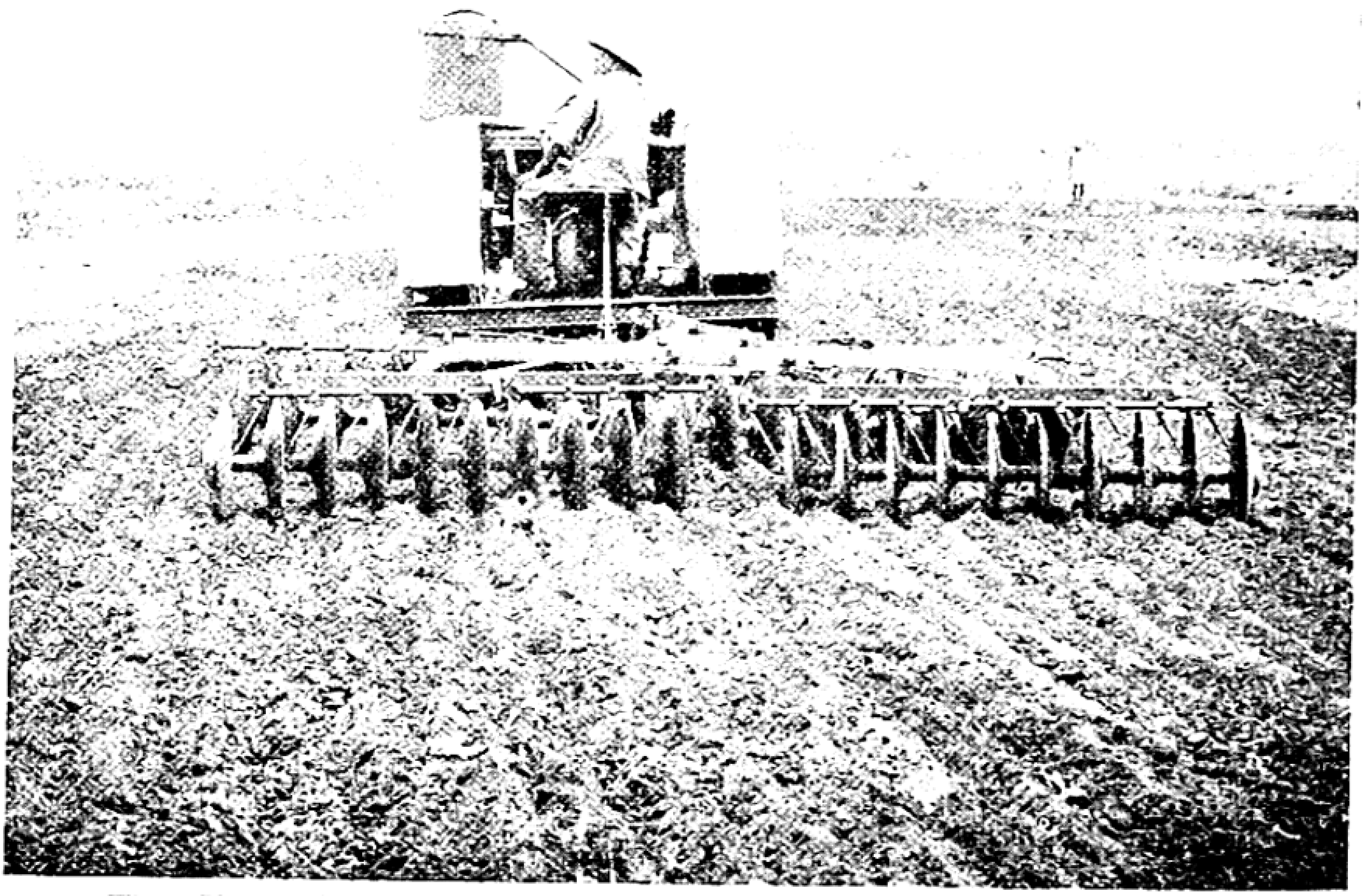
Charcoal Gas Tractors.—Reference has already been made to the scope for the use of charcoal gas burning tractors instead of the kerosene or other oil tractors, as a means of not only cheapening the cost of tractor operations but also of avoiding the dependance upon these oils which have to be imported from abroad and whose supply is subject to uncertainties and even of absolute stoppage. The Mysore Department of Agriculture was probably the first in India to adopt the use of such tractors and one such was made available for custom ploughing on hire to farmers who wished to hire it. The tractor was a 25 H.P. kerosene tractor which was adapted to the use of charcoal gas in the same way as many lorries, buses and automobiles have been fitted up in recent years. The cost of ploughing with this outfit was only Rs. 2-8-0 to Rs. 3-8-0 per acre as against more than double this sum for kerosene tractor (figures relate to the year 1940). The tractor was found quite capable of tackling very stiff sod overgrown with many tussock grasses and other vegetation.

Area Worked per Hour.—A method of reckoning the area that will be worked per hour by various tillage implements approximately has already been explained (*vide* page 155). In regard to these tractor-drawn implements, another rough and ready method of calculation which is adopted by tractor engineers and which may be found useful is as follows:—Multiply the width of working (in feet) of the implement concerned by the speed at which the tractor

The Kerosine Tractor adapted to Charcoal gas, referred to in the text, working a heavy three furrow plough. *Photo by Mys. Agr. Dept.*

The I.H.C. Caterpillar Tractor T.D. 6, with the tractor cultivator on the Ooragahalli Estate, referred to in the text. Four months old sugarcane crop in the background.

Photo by Author



The Charcoal gas tractor working a large double gang disc harrow.
Photo by Mys. Agr. Dept.

travels (in miles) and this figure will represent the area in acres of the extent which the outfit can be expected to cover in the course of 10 hours, making allowance for the turnings at the headlands and ordinary stoppages. A six-foot disc harrow which on good soil can be pulled at the rate of $3\frac{1}{2}$ miles per hour, will thus cover 21 acres in 10 hours, which is a figure not far different from what may be arrived at by the method already explained, when stoppages are allowed for.

Some Recent Figures.—As regards the amount of work turned out, the time taken and oil consumed, the following performance record maintained for tractor work on a large farm not very far from Bangalore during the season of 1948 will be found very instructive:—

Tractor No. 1.—International Harvester Co. Caterpillar tractor T.D. 6 (35 H.P.) using high speed Diesel oil, consumed 60 gallons of the oil, worked a $7\frac{1}{2}$-foot rigid shank cultivator during a period of 40 hours altogether and covered an area of 80 acres. The depth of working was fully 8″ and the soil was the red stiff loam or ragi soil common around Bangalore. The soil was in very good shape for working on account of a good shower of rain. The field was left in a condition quite as good as if not much better than could be brought about by several ploughings with a country plough.

Tractor No. 2.—Fordson Row Crop Tractor (28·5 H.P.) mounted on water-inflated pneumatic rubber tyres and using power kerosene, worked altogether 120 hours on an area of 30 acres, preparing this area for the planting of sugarcane. The soil was fairly heavy clay loam. The implements used were a 12″ three bottom plough ploughing 10″ deep once, rigid shank cultivator once, coil shank cultivator once, then opening deep furrows with a three bottom furrow-opening or ridging plough (all of them being I.H.C. implements). For the 120 hours taken for all this work the oil consumption was 200 gallons. The author inspected the work twice during its progress and can testify to its excellence. (Figures relate to the Ooraghalli Estate, about 25 miles from Bangalore and kindly supplied by the owner Mr. N. Krishna Iyengar, a remarkably capable agriculturist.)

The successful use of tractor outfits is however one of organisation. Even for the best among our agriculturists the owning of such outfits must be ruled out on account of the very high prices ruling now for such outfits and for the comparatively short period of time that it may be required during the year. No private farmer, moreover, can dare to face breakdowns at critical moments which is a contingency which cannot be ignored even with a very good repair service. In the U.S.A., farmers telephone to dealers in case anything goes wrong and the necessary spare parts are flown to the farm in charge of a mechanic. Even then the risk of breakdowns is a much dreaded feature of tractor ploughing and other mechanical operations. It has been humorously observed that in India one should invest in two tractors in order to keep one tractor going (we

may even say three will have to be kept), so great has been the trouble with breakdowns in the past. Many pioneers in that work have bitter memories of the expense and annoyances caused. All things considered therefore the outfits will have to be owned by special agencies of professional men or by the Government who can equip themselves with the facilities for repairs and renewals to cope with breakdowns promptly. The organisation should be such that the fields belonging to a whole village or villages can be ploughed up with the very first heavy rains, leaving the subsequent cross-ploughing, cultivating, clod crushing, etc., to be attended to by the farmers themselves with their bullock labour; this latter work will of course be comparatively light and capable of being finished quickly and without much strain. If the organisation is efficient and the work carried out without a break and at a moderate cost the system may become a permanent part of rural economy and conduce very materially to increased crop production.

Before closing this particular aspect of tractor work, we may state that within the last few years, the introduction of tractors has been attempted on a scale which could not have been thought of in the past, and its history spotlights the difficulties incidental to their working and the great need for providing against them, to which we have referred. As part of the "Grow More Food Campaign" and in order to clear and bring under cultivation within a short space of time, vast stretches of jungle land infested with kans grass and scrub vegetation and in order further to enable private land-holders to derive the advantages of tractor ploughing, a very large number of tractors were bought by both the Central and the State Governments and special organisations were also set up to carry out the work. The tractors were not only large in number but also comprised many types, models and sizes, thanks to the enterprise of the trade. In Mysore alone there were for instance a fleet of 147 tractors of diverse types. The expenditure was colossal but so great were the results expected that it was considered justifiable. In actual working, however, the organisations met with all the troubles to which we have referred, in full blast, not to mention serious defects in the management in addition; breakages, lack of spare parts, breakdowns due to lack of technical knowledge, lack of sufficient trained personnel, and so on; put such a large number of the machines and implements out of commission, as to bring the work almost to standstill point. An official investigation followed, as the result of which the agency was overhauled and put on a better footing; much valuable experience was gained although at a staggering cost, and the mistakes are not likely to recur.

It also happens that many of the large tractor manufacturing companies, especially of the U.S.A., have entered the Indian market and are making a more or less all-out effort to popularise the use of tractors. As part of this effort they are providing an efficient and prompt spare part and repair service. Some of them have even

opened their own training schools for tractor operators and mechanics, who will be available not only for managing both tractors and tractor-drawn implements with knowledge and skill but also to train more operators in their turn. Both these circumstances, *viz.,* the more business-like appreciation on the part of Governments of the possibilities of tractor cultivation in this country and the new enterprise on the part of the tractor companies to provide efficient repair service, may be expected to promote the use of tractors more widely and more efficiently.

Garden Tractors.—Reference may be made in this connection to the outfit called a Garden Tractor and the tillage, seeding and interculturing implements that go with it. These are small tractors which are similar to the walking ploughs, that is to say, the operator does not ride on the tractor but only walks behind it guiding it with a pair of handles, just like a ploughman walking behind an ordinary plough drawn by bullocks or horses. These are very handy, turn within a narrow circle and can be used on ploughed land also for various post-ploughing tillage operations and other work like a bullock-drawn implement. For the same reason they can displace bullock labour altogether. These have not been tried in India (at any rate none has been reported) and it is very difficult to say to what extent they will prove useful under Indian conditions. It is however very likely that they will not have enough power to do ploughing satisfactorily. Many years ago the author had occasion to try one (on a somewhat stiff soil, it must be said) and found that the machine could not do the work properly. Recent models may be and are probably great improvements, at any rate they are reported to be rapidly growing in popularity in the U.S.A. It must also be noted that they are only *walking* implements and can therefore work no faster than a man can walk on ploughed ground at the best and the capacity too is limited to a single plough bottom. The result is that it cannot possess the chief and most important merit of tractor ploughing, *viz.,* speeding up of work. Whether the 'Roto-tiller' arrangement will work better cannot be stated. The engine is said to be petrol-driven and that means very material increase in cost of working. Probably the ordinary farmer or ploughman cannot operate it without the risk of damage and this will also count against it in regard to its suitability to Indian conditions. Of course these are considerations which occur *prima facie,* actual trials under different conditions will have to be conducted before its merits or suitability can be correctly judged.

B. Haulage or Road Tractor

Tractors can be employed, when the need arises, for hauling materials from and to the farm. This use may to some extent be limited by the kind of wheels which are fitted to the tractor and also by the kind of trailer or truck which is available for loading the materials in. Road authorities generally forbid the use of certain

types of tractors on the road, even when they are only propelling themselves. Ordinary steel wheels do much damage to the road surface, even when they are only smooth-faced; but all agricultural tractors have generally wheels which are shod with thick and somewhat sharp lugs across the face of the tyre and these can easily make havoc with the road surface, a consideration which applies to tractors of the caterpillar type also. In order to prevent such damage, these wheels are fitted with (detachable) wooden or metallic cleats which fit in between every two lugs and render the wheels smooth-faced. These will have to be fitted whenever road haulage has to be done and removed when not necessary, the change being made every time road haulage is taken up. In addition to this question of damage of road surface the very slow pace at which alone such tractors can travel on roads, will also very much restrict the use for road haulage. The scope is therefore limited to tractors with rubber tyres, which are now becoming rather general with agricultural tractors. The use of rubber tyres has indeed become so general that road haulage must now be considered an important field for the use of tractors.

On the farm itself, for hauling on earth tracts or roads or over the fields themselves when the crop is not on the land, for the haulage of many kinds of material, the kind of tyre or wheel does not matter so much and all tractors should have scope in this respect. What applies to the wheels of tractors applies also to the wheels fitted to the trailer or truck. Specially large trucks with a wide base and capable of taking large loads of bulky material like the sheaves of grain, jowar stalks, sugarcane, straw or manure over the rough surface of the farm will be of great use, especially in a very undulating or hilly country.

C. Belt Work

An important use for agricultural tractors is as a source of power for driving machinery of various kinds on the farm, if such should be in use. Threshing, pumping water for irrigation, milling sugarcane, cutting fodder, sawing wood, etc., are operations on the farm for which machines driven by power can be and are used. It may be possible to make use of the tractor for driving one or other of these machines, when it may be free for such use. Many tractors are provided with a pulley attachment for belt drive and possess ample power for the purpose. As a source of power the tractor has the advantage that it can be removed from place to place and used wherever the machinery may be installed. Some kind of intermediate pulley will be needed in some cases, for altering the gear and making the tractor speed suit the machine concerned, and other adjustments may also perhaps be necessary. It is needless to say that there is very little experience at present (at least in India) to be guided by. These uses obviously presuppose the existence of the various kinds of machinery on the farms, which at the present time

is not the case. The scope can increase only hand in hand with a development in the use of such machines. Pumping water for irrigation offers perhaps the greatest scope for the supplementary use of tractors and this deserves development. It is reported that a portable pumping set forming part of a tractor equipment is being introduced and if this should be successful then the scope for the use of tractors distinctly improves.

These two kinds of use of the agricultural tractor, *viz.*, haulage and belt work, are only subsidiary uses, the main use being that of ploughing and other forms of tillage.

CHAPTER XXIII

PREPARATION AND STORAGE OF PRODUCE

NEARLY all crops have to undergo some process or special form of preparation or handling, before it can be called a marketable or commercial product. In some cases these processes convert the produce of the field into a totally different article, as in the case of jaggery or sugar, from sugarcane, in which the methods are fairly elaborate or as in the case of the extraction of fibres from sannhemp, jute or aloe fairly simple. In other cases the produce of the field does not assume such a totally different form but somewhat intermediate in character, generally with the object of making it suitable for being kept and handled like a commercial product; examples are furnished by coffee, arecanut, ginger, turmeric. In still others it is a simple form of drying as in the case of chillies, pepper, cardamom, etc., in which the prepared produce does not differ very much in shape from the raw product as it comes from the field. In the large majority of cases as in the case of the grains, pulses and oil-seeds, no such preparation is involved, but the general principles of ordinary drying, cleaning, grading etc., apply to them as much as to any other produce.

The full advantage which ought to accrue to the grower, whether in the shape of money or storable produce for his own consumption cannot be derived unless proper attention is paid to this conversion in all its stages. In fact if owing to lack of knowledge, skill or facilities the produce is not prepared in the proper way, the produce may suffer both in quantity and money value which is tantamount to a lessened production. As a matter of fact, it may even happen that the cultivation may result after all in a net loss, owing to this circumstance. On the other hand where the preparation has been of a high order, it will greatly add to the value of the produce. Due attention to this end of the year's agricultural operations must therefore be regarded as one of the factors of production.

Many of the crops have each its own individual or special methods, but the principles are common to most of them. We may now briefly refer to these general principles, taking the more important crops, as illustrations.

STAGE AT WHICH CROPS SHOULD BE HARVESTED

It is necessary that crops should be cut or harvested at the time which is most appropriate to each. For example, sugarcane has to be cut when the cane is fully ripe, that is to say, when the sucrose content is highest and the glucose content sufficiently low; if cut before or after this stage, not only does the sucrose content suffer in percentage leading to a lesser yield of sugar but the glucose content is also higher than it should be. This results in a poor quality of jaggery when jaggery is made or a reduced outturn of sugar when

sugar is made. In either case, the full advantage of the crop is not derived, if this essential condition is not observed. In a crop like indigo likewise, the crop has to be cut when the leaves will yield the maximum quantity of dye, and this applies to special products like medicinal herbs and plants, essential oil-yielding plants, rubber, cinchona, etc., which have therefore to be cut or tapped or stripped, as the case may be, when the yield of the essential constituent is at its maximum. Similarly, in the case of the fibre plants like sann-hemp, linseed, jute, etc., cutting has to be at the proper stage if fibre of the best type is to be obtained; at an earlier stage, quantity and even quality may suffer and at a later stage quality may suffer, and in either case again the full advantage of a heavy crop cannot be obtained. It is only about the time when the crop is in full flower and before the pods begin to ripen that the fibre of the best quality, both smooth and strong, and almost the maximum in quantity can be obtained. The stage to cut may sometimes depend upon the kind of produce which is expected to be the main product; for example, it may depend upon whether it is the fibre or the seed which is the main product, and one will have to be sacrificed to the other, or a balance struck which may depend upon circumstances. In the case of the cocoanut, for example, the fruits are gathered in different stages of ripeness, and even when they are over-ripe and dry, depending upon whether the nuts are to be used as fresh nuts, or to be dried into copra for oil or consumption, or to be made into the special kind of copra called "Kottai", "Gittuku". The fibre obtained in each case also varies in quality, the overripe fruits giving practically useless fibre and the half-ripe fruits giving fibre of the best quality. Similarly in the case of oil-seeds like groundnuts, castor, etc., if they are not quite ripe, they may contain free fatty acids which will give rise to rancidity in the seed, if stored, and in the oil made therefrom. Mere mechanical considerations may also influence the time to harvest; for example in the case of the gingelly crop, the harvest takes place somewhat before the pods are fully ripe and the ripening is completed only in the stack. Otherwise, if left on the field till the pods quite ripen, the pods will split open and shed the seeds, occasioning heavy material loss. Castor too suffers from the same disadvantage, as the pods will split and scatter the seeds but this loss may not be anything like that in the case of gingelly; as with a little additional labour the ground can be swept and the scattered seeds gathered. In arecanut the quality usually made in Mysore requires harvesting just when the nuts are only about three-quarter ripe, when the thumb-nail can, for instance, be easily thrust into the outer cover of the fruit; ripeness above this stage lowers the quality, the ripest being the lowest. Much care and labour have to be spent in ensuring that the largest bulk of the nuts are gathered at this stage, the harvesting for this purpose being carried out three or four times at intervals as the bunches ripen only one after another.

In most crops the risk which is most commonly dreaded is over-ripeness. In nearly every case and especially in grain crops this leads to shedding and loss of grain, which may become very serious when in exceptional years harvesting has to be delayed by wet weather or lack of labour. Premature harvesting will however necessitate considerable drying later on and may even slightly lessen the quality for certain purposes. In large-scale mechanised farming, this is considered a lesser evil than the risk of overripeness and a crop like rice is harvested a little before it is dead ripe and subjected thereafter to artificial drying to the correct stage (generally to a moisture content of about 14%); such grains are reported not to break so much in the milling and that the outturn of whole rice is higher than in dead ripe harvested crop. Even in small-scale farming, it may be advantageous to harvest before the dead ripe stage, and allow the further ripening in the stack itself. Both ripening and drying take place in the stack to some extent, which will thereby complete the ripening process; in this way the need to hurry and the risk of rain, shedding, etc., may to some extent be avoided. In all crops, even with the best attention paid to the time and method of harvesting, there will be a fair percentage of both under-ripe and overripe portions along with the main bulk which of course will be in the correct stage. This will necessitate considerable separating out and grading of the final produce.

Care in Curing, Extraction and Preparation of the Special Products

In the case of crops like sugarcane the methods of extracting the juice have to be thorough so that as much of the essential ingredient (sugar) as possible may be extracted and the waste reduced to a minimum. In the ordinary methods of milling in bullock-mills, the extraction may not exceed about 65% on the weight of the cane and if the fibre is taken to be about 12%, then 20% to 25% or a fourth of the juice will be left in the bagasse or crushed refuse. Efficient mills will mean a considerable reduction in the loss. Likewise in the methods of manufacture, attention to liming, skimming, correct boiling and other essential details will yield a jaggery of good quality while negligence or lack of knowledge will result in a product which may not fetch even half the price of the better class product.

Likewise a crop like tobacco, which is also mostly cured on the farm itself with the common local varieties and even in centralised flue-curing barns, details of curing have to be closely attended to and experience and skill count very much. With the same kind of leaf, lack of care may produce a cured product which may be worthless and fit only for the manure heap while an experienced curer may turn out a cured product many times more valuable.

Indigo is another example, and the outturn of the solid marketable dye requires great attention to the details of the process from

beginning to end. The same remark applies to many other crops and even where curing or manufacture is done on a large factory or plantation scale and methods are standardised and closely controlled, there is always need for watchfulness against a reduction in quality of the product.

There are crops in which only the simple process of drying in the sun is to be carried out; though in a few some preliminary process is also involved. For example, the arecanut kernel is cut and boiled or boiled whole, for a short time (the correct stage being when the germ is loosened out) and then put out to dry. Turmeric is also boiled whole or sliced and then put out to dry. Ginger has to be peeled, steeped in water or water containing lime in successive stages and then dried. In some cases a certain amount of bleaching is carried out on the farm or plantation itself after the drying as in the case of ginger and cardamom. Some of these are more or less specialised and the details of the process will have to be followed carefully, in order to ensure a product of good quality. Each crop has its own special features but the principle, regarding the necessity of obtaining the maximum outturn and maintaining a high quality of produce, applies to them all.

Even in the case of the ordinary grain crops, damage and deterioration may arise if the stacking was unsatisfactory and rain was allowed to enter the stack, or the sheaves themselves were put in the stack when they were not sufficiently dry. Much mouldiness may result in the grain, as a consequence, which will reduce its quality whether for home use or for sale. Stacks have to be built on firm elevated ground or special low platforms on stone slabs to avoid white-ant damage. Sheaves have to be dry enough and the weather clear during stacking and the sheaves put in with the grain ends completely inside and well pressed, the stack built tight, conical or pyramidal in shape but always with a steep gable top and projecting eaves.

Quality of Product should Suit Markets

It must be noted that various markets have special preferences, which have become customary and only these qualities will find a ready and profitable sale. It will be therefore necessary to suit the kind or quality made to the market to which the neighbourhood or tract usually caters. This is particularly noticeable in the case for example of jaggery, arecanut, cardamom and tobacco. In the case of jaggery particular markets favour cubes, some large, some small, others favour large ball-shaped lumps, others very small marble-like lumps, still others slabs, or cylindrical masses like large cheeses, or powdered like sugar; some may fancy light-coloured grade and others dark jaggery, because it will keep better in the rainy months. In the case of arecanuts many grades are customary, whole dead ripe nuts without any treatment and as they fall from the tree (or after drying), nuts gathered at an earlier stage and prepared by boiling

and drying, and among the latter, whole, sliced, bruised, or shredded. The quality and grade made on the farm have to be the kind favoured by the customary markets. In tobacco, likewise, there is a large number of special forms as it is cured and marketed and for each of these there is a special market. Special varieties too are grown for special forms of produce. Curing for snuff, chewing, cigars or cigarettes or *beedies* has to be done differently and the qualities attempted should be in accordance with the variety and the market requirements. In the case of cardamoms also some markets prefer the green cured, others the straw-coloured ones, and still others only bleached ones; even among these kinds the round or long fruits will have to be sorted out, as different markets fancy one or the other. The same principle applies to many other products.

Whatever may be the grade or kind made, the quality should be high and this requires both skill and knowledge. High quality always tells in the long run and the estate or individual grower or village producing such acquires a name and special mark which connotes quality, and is therefore offered a premium in price even before it is inspected by the buyer.

Other Requirements.—There are however some other qualities in the type of produce which every one can easily secure and which do not require any special skill. Under this category comes, firstly, cleanliness. Produce should be cleaned by winnowing, sifting and garbling, etc., in order to remove dust, foreign matter, chipped, broken, or discoloured portion, etc. Secondly, it should be sorted so as to remove at least the inferior grades, even though special grading according to market requirements may not be done; the so-called "bulk quality" itself should be fairly high class. The more uniform any lot is, the better it is fancied. Thirdly, produce should be uniform throughout its bulk and true to the sample that may be furnished. In the trade discrepancies in this regard are heavily penalised, even though they may arise by negligence rather than any intention to defraud. Fourthly, produce should be honest, *i.e.*, should not be tampered with in order to give it additional weight or volume. Watering or increasing the moisture content deliberately is a common fraud but growers forget that traders protect themselves amply against such practices by substantial reduction in price for such articles. Adulteration with materials closely resembling the produce or with inferior but indistinguishable grades, as in the case of small grains, is also a common vice which in the long run does not pay.

STORAGE

The quality as well as the quantity also suffer seriously in storage, more or less according to the method of storage adopted and the care bestowed. In nearly all cases produce has to be stored by the grower for his year's consumption or prior to being sold, for

periods which will vary according to the grower's need or the state of the market. It is only in the case of bulky products like groundnuts or cotton in which even the produce of a few acres will require more room than the grower can afford or products which may deteriorate or undergo loss in weight that it is sent to market without being stored for any length of time. Storing produce is therefore unavoidable and every care has to be taken to see that the losses incidental to the process are kept at a minimum if not avoided altogether.

Loss in storage occurs (1) in actual quantity owing to the ravages of rats, sparrows, etc.; (2) in quality due to mouldiness arising from dampness or exposure or the entrance of water; (3) in both quantity and quality owing to the havoc of insect pests peculiar to stored produce. The last is by far the most common, the grains are bored and eaten through and reduced to hollow husk or powder and the insects teem in enormous numbers and added to their dead remains and the dirt, make the produce disgusting and unfit for consumption. The loss due to these causes is enormous and is estimated at something like $3\frac{1}{4}$ million tons of grains in India annually, and accounts for a large reduction in the yearly production, acting, so to speak, as a negative factor of production.

Reducing Loss in Storage

Losses in storage can be kept down by (1) thorough drying of the produce in the sun and thorough cleaning so that it is to all appearance at least free from insect pests; (2) attention to the method of storage and the kind of storage receptacle or room used; (3) special treatment of the stored produce in the store.

1. *Cleaning and Drying*

The thorough cleaning of the produce removes to a large extent living pests, and cocoons and larvæ and even to some extent egg-masses. This precaution therefore reduces the chances for a large increase in the pest after and during storage. Drying the produce thoroughly makes it less attractive or suitable for the pest, by the mere reduction in the moisture content of the grain. In fact if the moisture content in the grain or pulse is only 8% to 10%, few insects can breed in them. Sunlight moreover is credited with a certain amount of lethal effect upon these pests, so that when the grain is dried in the sun as is ordinarily done (as against artificial drying in large-scale work) it becomes doubly effective. In fact even after storage a periodical putting out of the grain in the sun for drying is a very desirable measure of control and it is advisable that all grain stores should have a large enough drying yard attached, with a good cemented floor on which the grains could be spread out to dry in bright sunshine, without any risk of mixture with earth or dust.

Drying is indeed the first requisite in storing grains. If produce is not sufficiently dry, it leaves the door open to the most serious kind of deterioration, *viz.*, that due to mouldiness. Sun-drying will of course effect this along with the other advantages mentioned above; but if on account of the weather or other reason, sun-drying is not possible, then artificial drying will have to be resorted to. Such artificial drying or sun-drying, if possible, will have to be resorted to again if the weather is very humid and the grain has absorbed more moisture. The storage of produce which is not sufficiently dry to the required degree and not cleaned to the extent possible is in fact a very fertile source of damage by insect pests.

2. *Methods of Storage*

These relate to the form of storage, *i.e.*, in bulk or in bags and to the kind of receptacle or store-house employed. The simplest and least satisfactory method is to dump the grain or other produce in a heap in any odd room, where it is exposed to the ravages of all kinds of vermin, even though it may be well protected from the elements. In these loose heaps the conditions are very favourable for infestation by, and rapid increase of, the different storage pests like weevils and moths. Special well-built rooms may be set apart as stores, but when the grain does not fill the room or structure completely, as is very often the case, the conditions for the increase of pests are more favourable. On the other hand if the grain or pulse is filled into bags and stitched tight, the conditions are less favourable, though infestation cannot be prevented. It does not matter moreover if the room is quite full or, only partially full. Storage in bags has other obvious advantages in handling, but the expense is against it and growers usually prefer therefore storage in bulk.

Underground Storage.—A common and rather primitive form of storage in bulk is that of pits or large pot-like excavations underground, or small rectangular pits, the sides of which in both cases being raw earth or plastered. The main drawback in the method is the risk of moisture from the ground spoiling the grain, if not water itself seeping into it and ruining it altogether. If excavated in situations free from this risk such as on elevated ground and in hard impervious soil and if as an additional precaution the pits are lined with cement plaster, there is much to be said in favour of this cheap method. In fact it is reported that in Northern India, the old-fashioned pits for strong wheat have now been largely replaced by cement cisterns. Insect pests are not however ruled out, especially when the pits are not very deep.

Above-ground Storage.—Tall cylindrical structures like silo towers, made either of sheet metal or good masonry, will provide the necessary depth of the grain which largely excludes the air from the bulk of the grain and therefore prevents insects from breeding. An additional precaution in such cases is furnished by spreading a layer of sand about 2″ thick over the surface of the grain which will act

as a seal. It has been found in this method that even when weevils are present, they do not multiply; adults both male and female creep through and up the grain and the sand on it to the open surface, driven by the instinct to pair and breed. They are however unable to crawl back again into the sand and the grain and simply perish on the surface. This simple precaution is specially useful where the bins are not large-mouthed and is very suitable for ordinary individual requirements. Masonry or metal cylindrical bins may be erected either inside of godowns or out in the open. In the latter case they must of course be well protected by substantial rain-proof covers or roofs, whose eaves will project well over and beyond the rim so as to keep out beating rain. The flooring is equally important and should be fairly elevated and made of at least a foot of hard cement concrete or of granite slabs dressed and made to fit tight at the edges; this is very necessary to keep out bandicoots which can burrow through and under the bins or storehouse floor, if it is only of earth or even concrete of insufficient thickness. Glass broken into very small bits is sometimes mixed with the mortar or cement used, as an additional material for preventing damage by bandicoots. A suitable opening at the bottom for drawing out the grain when needed which can be shut tight thereafter should be provided and this is not always easy to arrange satisfactorily. A crude but clever device is provided by an ordinary cocoanut shell whose convex face sits tight against the rim of the opening inside the bin and which can be pushed in for opening or pulled to for closing the outlet hole acting something like a ball valve in a suction pump. Shutters made of sheet metal or wooden plank which move in a groove either up and down or from side to side against the face of the opening form more serviceable devices and can be locked after the grain is drawn, if desired.

Storehouses may be substantial masonry godowns or rooms in which the grain can be kept in loose heaps, large or small. Such structures should have a good elevated basement, thick cement concrete floors, smooth walls and rounded corners with no cracks or crevices in which insects can hide and breed, ventilators which can shut airtight when necessary and provided with close wire-netting to keep out sparrows, squirrels, etc., and the doorways protected at their bottom by strips of sheet metal to keep out gnawing rats and for shutting tight. Grain in these rooms can be kept loose or stacked in bags, preferably in separate stacks of moderate size with plenty of space around each for workmen to move about, and for inspection, cleaning, etc.

The main principles to be borne in mind in the construction of such storehouses are: (*a*) to avoid damp, firstly, from actual leakage of rain through the roof and by being beaten in through doors, windows and ventilators, secondly, from capillary moisture creeping up through the floor and walls, which has to be prevented by the interposition of a damp-proof course in the wall and by stone or

asphalt for the floor, and thirdly, from moisture condensing on the walls and in the interior generally, which can be avoided by frequent and good ventilation; (*b*) the prevention of the entry of sparrows or other birds through open windows and ventilators, which should therefore be protected by wire-netting, and of rats, squirrels, etc., along and up through rain-water pipes, drains and other openings and of bandicoots burrowing through the floor and under the walls; (*c*) to afford no possible harbourage to insects in cracks, holes, corners in the walls or plaster, in between boards if timber is used, and in shelves or brackets if these are provided. Constructional details, of which some have been indicated above, may vary according to circumstances and some may be elaborate and costly; but if the principal requirements of a good store are kept in view it will be generally possible to secure most of them without incurring very great cost.

On a small scale grains and pulses are stored in bins or receptacles of various cheap local materials such as earthenware pots, large or small, wickerwork or bamboo mats well plastered over or in bundles of straw twists and so on, according to local custom. Flat sheets of tin or the halves of round gourds nailed or fastened on the legs of stands on which the bundles may be kept serve to intercept and keep out rats. None of these however are quite insect-proof but are liable to damage more or less according to the care taken, the extent to which the grains or pulses were free from infestation when they were put in, tightness of packing and exclusion of air, dryness of the produce and so on. Various materials supposed to kill or keep out insects are sometimes mixed with the produce which may be intended for seed purposes; these however afford little protection and are of doubtful value. The sand cover referred to already is a very efficient and much better method.

Grain Elevators.—On a large scale grain is handled in bulk both in storage and in transport by land and sea. Storage in such cases is in the so-called "grain elevators" and transport is in special waggons or in the holds of ships specially designed for this purpose. The grain elevators are large, tall cylindrical tower-like structures or bins of varying capacities and in units of a dozen or more. Grain is hoisted or elevated into these bins by machinery in "bucket elevators"; grain can be drawn out through chutes at the bottom from which either waggons or the holds of ships can be filled for transport. Arrangements also usually exist for cleaning, drying and fumigation or other treatment when necessary, so that produce is well protected against damage.

3. *Treatment of Produce against Pests*

(*a*) *Before Storage.*—The all-important need for drying and cleaning the produce before being put in has already been mentioned. Reference has also been made to the mixing of various substances with the grain for keeping out insects. On a small scale

both grains and pulses intended for seed purposes, the latter especially, are treated in this manner and the materials used are wood ashes, fine earth or dust, chilli powder, turmeric powder, 'sweet flag' roots or powder, the leaves of neem and certain other plants and even the glumes and chaff of the grains themselves. Camphor, asafœtida, naphthalene and some lesser known rotenone-containing products like derris roots, *Mundelia suberosa* roots, pyrethrum, *Tephrosia candida* seeds, etc., are also used with some good effect. It is difficult to say to what extent these afford protection; a certain amount of palliative effect can however be expected but on the whole none of them can be considered satisfactory. The fine dusts of certain inert materials (like 'neosyl' or precipitated silica which has been recently recommended) of which fine wood ashes, charcoal powder, especially of charred paddy husks and even earth dust are the crude and easily available forms, are found effective; they abrade the body surface and abstract the moisture from out of the bodies of the insects to a degree that proves fatal and brings about their destruction. Another article used in the same manner is the metal mercury, a few drops of which inside the grain mass will also act as an insecticide as its vapour can destroy the egg masses completely.

Inside of well-closed bins or receptacles (and not when the grain is heaped loose and exposed) the method will be found effective. The simplest and most serviceable method for the small-scale storage is the sand seal described already; it can also be used for large-scale storage if the storage bins are designed suitably to the method. This simple method has the great merit that it does not affect the germinating capacity of the grain nor its fitness for human consumption.

(*b*) *Treatment in Storage*—(1) *By Carbon Bisulphide.*—Produce in storage becomes infested with insect pests more or less according to the circumstances described above and in such cases it has to be treated with insecticidal materials. The best recognised insecticides which have been found both efficient and suitable where grain or pulses are intended for consumption are carbon bisulphide and hydrocyanic acid gas (and latterly the chemicals carbon tetrachloride and ethylene dichloride). Both are highly poisonous and the former is in addition highly inflammable and volatile and are therefore dangerous, unless strict and proper precautions are taken. The treatment should be carried out under the supervision of experts. The storage godown has to be shut completely (with the exception of the doorway for the operators to enter and come out) all the windows and ventilators are closed and all interspaces between the shutters and walls clayed up, so that the store is quite airtight. Carbon bisulphide is poured in shallow saucers placed over the heaps or stacks of bags at intervals, and the operator comes out at once, the door shut and all chinks clayed up. The carbon bisulphide is a very volatile liquid, the fumes are heavy and therefore travel downwards into the heap, killing all insect life in the process. After the lapse of about 36 to 48 hours the room is opened, all windows

thrown open and the interior thoroughly aired before the workmen are allowed to move about inside. The quantity of liquid necessary for fumigation will vary with the extent to which the structure can be shut airtight and from 5 lb. to 8 lb. will be required per 1,000 cubic feet of space or at the rate of 2 lb. to 3 lb. per ton of grain fumigated. It need hardly be added that lights or the striking of matches near the premises should be strictly forbidden.

(2) *By Hydrocyanic Acid Gas.*—The hydrocyanic acid gas is also applied more or less in the same manner. The gas is generated in the store by special apparatus (which mixes the cyanide and the sulphuric acid when potassium cyanide is used) or by merely sprinkling crystals of calcium cyanide (cyanogas) in the room. This material decomposes in the atmosphere and evolves hydrocyanic acid gas and is itself converted into the innocuous carbonate of lime. The room is of course shut airtight and sealed immediately as in the first case, precautions being even more stringent. In about three days all insect life is killed out. The room is then opened with all precautions and fully aired before people are allowed inside. Per 1,000 c. ft. of space some 2 lb. to 4 lb. of cyanogas is recommended.

(3) Latterly, a new fumigant under the trade name 'Chlorosol' or 'Killoptera' has come into use, for this purpose. It is a mixture of three parts of ethylene dichloride and one part of carbon tetrachloride, and in contrast with the above two fumigants (1) and (2), is 'safe' and not attended with the risks of the latter.

(4) *Heat Treatment.*—From the point of view of safety, heat would appear to be the simplest agent for destroying store pests. If arrangements can be made so that the inside of bins or stores can be heated and the grain kept at a temperature of 145° F. for a period of ten minutes, then all insect life is killed out as it has been found that none can survive this temperature.

Some new insecticides are now coming into use, the most notable among them being "gammexane" which, it is claimed, can be used as a dust, as a spray or as a smoke. It cannot be said that this and other new insecticides have quite passed the experimental stage, especially in respect of their effect upon the suitability of the produce for seed and consumption purposes.

For example, 'gammexane' smoke has not been found to have any 'penetrative power' to affect grain stored in bags or kept in large heaps very deep in bulk. Their suitability in every case for seed grain or grain meant for consumption remains to be further studied. Nevertheless, as the result of trials conducted so far, the following recommendations which have been made for adoption may be found useful. These relate, however, only to grain intended for *sowing purposes and not for consumption.*

1. D.D.T. Mix the grain with D.D.T. (10%) at the rate of 1 part of D.D.T. for 10,000 parts of grain.

2. Benzene hexachloride (Gammexane). Mix the grain with 4% benzene hexachloride at the rate of 1 part for 10,000 parts of grain.
3. Pyrethrum dust. Mix with pyrethrum dust (diluted with chalk or talc) at the rate of 1 part for 20,000 parts of grain.
4. Naphthaline crystals. Mix with naphthaline crystals at the rate of 10 parts for 10,000 parts of grain.
5. Magnesium oxide. Mix with magnesium oxide at the rate of 4 lb. of the oxide for 1,000 lb. of the grain.

Treatments 1 and 2 are the best. (Taken from *Indian Farming,* Feb. 1950.)

As already mentioned such large-scale treatment with all the above-mentioned chemicals should be invariably carried out under expert guidance and supervision. Moreover it should be remembered that produce should not be allowed to be reinfested by the bringing in of infested grain into the store, in which case infestation of the already treated grain will recur again, needing a repetition of the treatment.

Preservation of Perishable Produce

Perishable agricultural produce like fruits and vegetables are preserved in various ways, so that they may be available at a time when they may not be in season and in countries where they cannot be or are not grown. These preserved products are however in the nature of manufactured commercial products and cannot be included among the fresh or slightly processed primary products with which we have dealt so far. The case of preserving fruits and vegetables, and other products like fresh milk, eggs, and even meat of various kinds over fairly long periods without deterioration, either in transport or in actual storage, is somewhat different and they are preserved as such without losing shape or form, and without any kind of processing. In both cases, the object is to make the fullest use of the produce without any of it being wasted or lost. These processes of preservation therefore greatly add to the productive capacity of the community and may be considered as factors in increased crop production. A brief description of the methods employed may therefore be given, before closing this section.

(*a*) *Refrigeration.*—The methods adopted comprise refrigeration, drying or dehydration, preservation in sugar or salt, and sterilisation. Refrigeration or preservation in cold storage is largely adopted in the case of the fresh produce mentioned above. The method is principally intended for the transporting of such products by land or sea from large producing areas to distant consuming tracts or centres. The transport may take days or weeks during which the produce has to keep quite fresh. Special cold storage steamers where the inside of the holds are maintained at a freezing

temperature are provided for ocean transport and shiploads of bananas, oranges, etc., are carried in this way. Railways provide refrigeration cars for the transport of the same class of goods, including milk, eggs, meat, fish, etc. The inside of the cars is cooled by blocks of ice packed at the side or the vegetables themselves covered over with ice. Even after arrival at the destinations warehouses provide cold storage. The chilling process may sometimes take the form of actually freezing the fruits and preserving them in this condition until required, when they have to be thawed out. Domestic refrigerators, both large and small, and portable or built in, are being installed in increasing numbers in both city and farm dwellings, where perishable produce at surplus seasons, is preserved for use later on. The principle on which the method is based is simply that the life processes are brought to a standstill by reducing the temperature sufficiently low; there is no oxidation or breathing and therefore no breaking down of tissue and degeneration. The same result is sometimes brought about by preservation in inert gases (mainly carbonic acid gas) or even by coating the surface of the fruit with oil or paraffin and so shutting out the oxygen of the air.

(*b*) *Drying*.—The next method of importance is drying in the sun, with or without a preliminary immersion for a few minutes in boiling water or in dilute soda-lye in some cases (as for prunes). Many of the Indian vegetables are preserved in this manner. They are usually cut into chips or sections, bruised or pierced and then put out in the sun to dry; in about a week of such drying, they become dry enough to be kept in store. They may be put out whole and then dried but cutting or bruising exposes more surface and helps the drying. In many cases a preliminary softening and rupture of the cell walls is brought about by immersing them whole or cut in boiling water for about half an hour or less and then removing them from the water and putting out to dry. The boiling also kills moulds or decay organisms, if any, should be present.

This process is imitated on a large scale in 'dehydrating' plants, which are able to handle very large quantities, within a very short time and independently of the weather. The vegetables whether cut or whole, whether fresh or (more generally softened by a preliminary immersion in boiling water) are spread on trays, which move through hot air in a tunnel-like passage from which the steam carrying the moisture is swept out by powerful ventilating draft. A large number of vegetables, potatoes, cabbages, beans, spinach, etc., were being dried in this manner and supplied in pressed blocks and in special containers to troops in distant places during World War II. The partial cooking before drying serves to prevent enzymes from destroying the flavour, colour and vitamins of the vegetables. Fruit juice, particularly of the mango (of certain sweet but stringy varieties), fruit pastes of apricots, whole fruits like dates, apricots and grapes, are subjected to this process of sun-drying for storage and sale.

(*c*) *Preservation in Salt, Sugar, etc.*—Preservation in salt as in the familiar method of preparing pickles in every household is another method of utilising produce, both for its special quality and as a means of carrying over surplus.

Preservation in sugar is by far the most important method and is conducted on a large factory scale like a manufacturing industry. The method is largely confined to fruits, for obvious reasons, and is adopted in the case of all kinds of fruit (though many Indian fruits have not been taken up yet). Preservation in sugar may be of three kinds, *viz.*, what may be called wet, dry or semi-wet and dry. In the wet method, the fruits after being prepared by peeling, coring, pitting or removal of stones, slicing, etc., are put into syrup of a definite strength and the containers (glass jars or tin cans) heated for a specified time in water near boiling temperature, and then sealed airtight by special lids or capping methods, thereby maintaining a vacuum or air-free space in the tin. If the process has been carried out properly the material remains sound as long as it is kept unopened, but once the containers are opened and air allowed to get in then the contents cannot be kept for long and have to be consumed immediately.

In the second method (dry) the fruit, after preparation in the same way as in the first, is soaked in heavy syrup and made to absorb as much sugar as it can, taken out and soaked again in a second charge of syrup, the process being repeated until at the end of the process the sugar not only saturates the fruit but also encrusts it on the outside as crystals. The name "candied" fruit is applied to this product and it can keep without the need for airtight bottles or cans.

The third method is intermediate and comprises those used for the making of jams and marmalades, which are both heavily sugared products. Fruits either whole or sliced into shreds or squashed, or the fruit juice alone are boiled in thick syrup, during which process the water in the juice is all evaporated and a mixture (semi-solid in consistency) of sugar and the juice of the fruit results, which has such a high sugar content that no mould or other organisms likely to cause deterioration can grow in it and the material can therefore keep well even though in open bottles or other containers.

A somewhat similar highly sugared product fit for preserving is the "fruit jelly". The juices of certain fruits are adapted for this purpose naturally, because they contain (generally in the skins and cores) considerable *pectin* (which is necessary for making this product) and when boiled in sugar can assume the form of a jelly. In the case of fruits which do not contain sufficient pectin, the latter can be purchased and added in quantities sufficient to make the juice 'gel'. The guava and the wood apple (*Ægle marmelos*) among Indian fruits are said to make very good jellies.

These various methods of preservation help largely in the utilisation of surplus produce and the prevention of waste. For the many details of the processes in actual working, special publications should be consulted, wherein detailed instructions can be found.

CHAPTER XXIV

SYSTEMS OF FARMING AND SELECTION OF FARMS

PASTORAL AND ARABLE FARMING

FARMS AND FARMING can be divided into various classes according to the chief agricultural use to which the land is put. Broadly two divisions can be made, *viz.,* arable and pastoral farming. The former is the most important division and is really agriculture proper, where the land is cultivated and various different crops are raised.

Pastoral Farming

In the latter kind, *viz.,* pastoral farming, the land is usually under natural grass and the main purpose is to raise cattle, horses or sheep. In its least advanced form it is just leaving the land almost in a state of nature on which the animals are allowed to roam at large. These 'ranches', as such cattle farms are called, were at one time of enormous size; the animals which roamed at large were periodically mustered and taken away for training or for sale. In the case of cattle and sheep in the early days the wool and hides were the sole objects, and later on after the advent of refrigeration or cold storage on board ships (frozen) meat became equally important. Further progress has been in the direction of dairying, when milk, butter and cheese assumed the same importance. A system of grass farming, with much attention paid to the improvement of grasslands by draining, manuring, seeding with good grasses, mowing and hay-making, etc., has become part of the development, although it is still far from arable farming. This system of cattle farming (or 'animal husbandry') can be confined only to new and sparsely populated countries like the New World, Australia, New Zealand, etc., where extensive stretches of land are available for the purpose. Even among such countries it is only when the rainfall is favourable and well distributed and the country is perpetually green with vegetation that this kind of farming is followed on a large scale.

Other considerations may also weigh, when dairying comes to be the chief object of such farming, as in the case of Great Britain where it is found more profitable to produce fresh milk and meat on the farms and depend largely upon imports for the foodgrains or as in the case of Denmark where a highly profitable export market for butter and cheese induces the farmer to concentrate on this production and to put the land to such use accordingly, and import the foodgrains required for human consumption. It is a noteworthy fact that this tendency to export dairy produce goes on in that country to such extent that the population consumes only

the "butter substitute" *margarine* and exports the whole of the huge output of natural butter.

Transition to Arable Farming.—When however the land available is restricted and the population increases, this kind of farming has to include, and indeed does include, a large measure of arable framing. In fact as the density of the world's population increases the land will have to be tilled and such intensive arable farming adopted as will yield the largest amount of direct human food. It must be observed in this connection that animal husbandry is a comparatively wasteful system as far as the production of the maximum of human food is concerned; the utilisation of part of the production on the land for feeding to animals and then using them as human food is not an economical method, even allowing for the fact that animals convert into human food many of the agricultural bye-products which are unfit for human consumption. A high density of human population is not compatible with the keeping of animals for human food, on anything but a very limited scale both in numbers and in kind.

Arable Farming

(*a*) *Pure or Single Crop Husbandry.*—It is with arable farming therefore that agriculture is most concerned. Arable farming may be devoted to (1) crop raising only, a single crop or a variety of crops being grown, or (2) a kind of mixed husbandry in which a certain amount of animal husbandry may be combined, principally for the production of milk and milk products.

Single crop hubandry is generally adopted in large-scale agriculture by large capitalists or corporations or where conditions may be favourable for the raising of only one particular crop, as in the case of the majority of rice-growing tracts. Where only single crops are raised the need arises for purchasing many of the requirements, and in case the crop raised is not a grain crop, then for purchasing foodgrains as well, for the farmer and for his labourers. This will be justified only when the crop grown fetches a high price and the proceeds will cover all expenses and leave a large margin of profit. Such farming is subject to the fluctuations in market prices for the produce and is attended with the risks usual in such cases. On the other hand there is much specialised attention paid to the actual crop raising itself, such as the use of high-yielding strains, adequate manuring, prevention of pests and diseases and the employment of labour-saving machinery. These are characteristics of large-scale farming by large land-owners or on farms created purposely by combining many small farms as in the case of the collective farms of Soviet Russia.

Even in small-scale farming, single crop farming is necessitated in India in tracts where rice is the main crop or sole crop grown. If irrigation is from channels or rivers, there may be only one crop

season, coinciding with the S.-W. monsoon, or if special storage facilities, such as tanks or lakes exist, two crops may be possible. The lie of the land in terraces or the custom of the tract may dictate the growing of only rice. In the case of many land-owners the disadvantage peculiar to the system is often masked by the fact that they have additional sources of income in towns and cities. As far as the actual tiller of the soil is concerned this works as a great hardship; not only is work confined to only one season (which however is common to dry cultivation also) but the food crop itself becomes the cash crop, needing to be sold in order to meet the requirements of the household, with the attendant risk to the year's stock of food supply.

(*b*) *Dry, Wet and Garden Cultivation.*—The main divisions of farming in India are two, *viz.,* Irrigated and Dry (or rainfed), the first one being further divided into wet and garden cultivation. Wet cultivation is confined to annual and seasonal crops, which require abundant irrigation such as rice which is the principal crop or jute and a large number of other valuable crops like sugarcane, groundnuts, Cambodia cotton, etc., and many garden crops like chillies, onions, potatoes, etc. Garden cultivation also relates to permanent crops like arecanuts, cocoanuts, betel vines, pepper, etc. Irrigated farming is of course the most successful, valuable and desirable kind of farming, on account of the comparative certainty of the crop and the assured food supply and the profits which can be earned, in return for the labour and money invested. Irrigated farming can carry a heavier density of population and such land is most sought after, and fetches a very high price. The following description of the conditions of irrigated farming in California and the irrigated Western States of the U.S.A. generally brings out strikingly what indeed is well known about such farming in India. "The irrigated area represents 35% of the crop productive capacity of the tracts and accounts for 50% of the cash farm income of the region, although the area itself is only 2½% *of the total.*" In India too the old village communities have always endeavoured to assure to each family a share in the wet, garden and dry areas of the village land. Such a combination enables the holder to raise not only the food crops for his yearly use but also nearly all his requirements, on his own land including crops for sale for cash needs and above all to furnish sufficient work throughout the year for himself, his family and his men and bullocks.

It is of course impossible to attain this ideal everywhere and land will have to be dry farmed over the bulk of the country; but the advantage of such a combination will have to be borne in mind and endeavours should always be made to secure a good irrigation source. In the case of the individual farmer this will usually take the form of a good irrigation well, while in the case of Governments or large communities or capitalists, the construction of large reservoirs or dams across rivers, or large pumping installations.

Specialised Farming

Farming may be also differentiated according to the crop or work in which it may specialise, *viz.*, such as (1) the great plantation crops, coffee, cocoanuts, tea, rubber or cardamoms, etc., or of the annual crops like sugarcane, tobacco, cotton, etc., or the great orchards of citrus, grapes, apples and other fruits or the great vegetable farms where crops are grown for transport to long distances or for canning and preservation; (2) dairy farms where the keeping of dairy cattle and the production of milk may be the main line; and (3) poultry farms, piggeries and so on. These special farms are generally very large concerns in which the expenditure of large sums of money is involved and they are worked almost in the manner of factories or industrial concerns. In India with the exception of the coffee, tea and other plantations and a few large estates here and there, this type of farming is confined to only a few special regions and may be said to be comparatively negligible.

Mixed Farming

Ordinary farming in India is confined to crop raising alone to a very large extent and has the drawbacks of a mere single crop husbandry. This may be distinguished from 'mixed farming', which is the more desirable one and in which crop raising is combined to some extent with the keeping of livestock, principally milk cows and buffaloes, a few goats or sheep, some poultry, pigs and so on. Such a combination yields a better money income, provides work all through the year, a profitable method for utilising the coarse bye-products on the farm and a kind of subsidiary occupation to all the members of the household, without the need for employing special labour. In Mysore which is a great cattle raising country, the farmer usually resorts to this form of keeping cattle and earns a substantial income from the sale of bull calves and young stock. Most farmers moreover would love to raise all the food they require from their own holdings; the foodgrains, vegetables, milk and milk products and in the case of non-vegetarians the poultry, eggs and fresh meat of all kinds to the extent possible and hence prefer "mixed farming".

Another important consideration in 'mixed farming' is the return from livestock in the shape of farmyard manure and with most Indian farmers this is almost the sole consideration. Animals are kept more because they are the 'manure-makers' on the farm than because they yield anything of value in the shape of milk or milk products. As these 'useless' animals mean a serious drain on the slender fodder resources the advice is freely given that their number should be ruthlessly cut down and they should be replaced by a smaller number of efficient animals. Such advice is seldom heeded because it will result in a reduced quantity of farmyard manure, which under present conditions cannot be made up by purchased or artificial manures on account of their high cost.

Animals will have to be kept moreover for the purpose, if for no other, at least to make profitable use of what would otherwise be waste material on the farm. The straw, dressings from the grain such as husks and chaff, the shed grain on the fields, the refuse of the household kitchens, will have to be converted into human food through the agency of the cattle, sheep, poultry, pigs or rabbits according to the choice of the farmer. Where farmers do not reside in farmhouses on their holding but live together in villages and far removed from their cultivated land, then the sanitary needs of the village and the design of the houses themselves will not admit of this kind of combination of livestock with crop farming. Although rural economy or the customs of the people may thus preclude this system, still dairying and the keeping of a few milk animals may be quite possible and a combination even to that extent will serve a useful farming objective. The general principle is however worth remembering so that it may be adopted wherever circumstances are favourable.

Intensive and Extensive Farming

Systems of farming are sometimes differentiated as 'intensive' farming, in which attention is drawn to the heavy duty put upon the land by which it is harnessed to the maximum productive capacity, the deriving of a big profit from a small area and cropping almost without respite, and 'extensive' farmnig which stresses the contrary features.

In *'intensive'* farming the area of the holding is comparatively small; the chief requirement for successful farming, *viz.,* ample irrigation is available and a large and ready market for all the produce that may be raised. The land is cultivated to perfection, manual labour being largely employed for deep digging, weeding and cultivation generally, heavy manuring is resorted to, and a succession of crops raised, and in each case every effort made to assure the highest yield possible. There is practically no rest for the land or labour on the farm, except a fallow at rare intervals to prevent the land from getting 'sick'. The farming is such that from a small piece of land a large profit is derived or sufficient livelihood for the farmer and his family. The farming is no doubt expensive and sufficient capital should be readily available and this is another factor restricting the area. Most vegetable gardeners near towns and cities adopt this system and indeed most farms under well cultivation are of the same type.

In *'extensive'* farming, the holding is large and ordinarily is dry-farmed. Yields are low or only moderate and often uncertain. Expenditure of all kinds has to be kept at a minimum, manuring is very discretely restricted and applied in a kind of rotation; purchased manures are seldom used and farm-made manures like cattle manure, green manure, soil amendments like tank silt, etc., are resorted to, in order to keep down expense; many labour-saving implements

and appliances are used and the cost of human labour kept down. Both for a living and for profits from farming, the owner depends upon the total yield from a large area rather than a big yield from a small area. Nearly all the dry-farmed areas are of this character and even among them the black cotton soil tracts are specially so, both holdings and fields being very large and methods of cultivation adapted suitably.

Farming Classified according to Ownership and Agency of Cultivation

The various classes of farming described so far are based upon the kind of cropping or animal husbandry to which the land is put. Farming may however be also classified according to the system adopted in working the farm, which is a totally different consideration altogether. On this basis farming may be classified as (1) Capitalistic farming under the ownership of a company or capitalist; (2) Individual farming or farming by the owner or tenant; (3) Collective farming.

1. *Capitalist Farming*

Capitalistic farming (also sometimes called 'Estate Farming') is generally confined to large farming or planting concerns. The owner, whether an individual or corporation, manages it like a manufacturing concern; he supplies all the working capital, and employs a manager through whom the whole business is conducted. All the labour is employed and paid just as in a factory, all the expenses for manure and other stores met, and the produce marketed and the profit and loss calculated at the end of the year, the owner—individual or company—enjoying the profit or bearing the loss as the case may be. Though it may be confined in India to the large plantations, elsewhere many farms are also managed in the same manner, a town dwelling wealthy businessman being the owner and managing the farm in the above manner.

Somewhat similar but carried on, it is reported, on a very large-scale are the so-called State Farms of Soviet Russia. In this case the owner of the concern is the State itself. The large area is farmed in the best manner possible with the maximum use of large-scale labour-saving machinery, the raising of the best varieties of crops, heavy and suitable manuring, and with protective methods against pests and diseases. The nature of the crops to be raised, the extent of land to be assigned to each project, how the produce should be processed and marketed or otherwise disposed of are all dictated by Government agency, and operations are supervised and carried out by Government experts, while the labour is provided by paid labourers, *viz.*, the dispossessed land-holders themselves, who have no kind of ownership or interest in the land.

2. *Farming by the Owner Individual*

This may take more than one form, *viz.,* (*a*) the owner-managed farm, where the owner himself resides on the farm or the village and attends to the carrying out of the various operations, employing paid labour for the purpose and himself only supervising. A large number of villagers who are forbidden by custom or caste rules from doing manual labour on the farm carry on cultivation in this way.

(*b*) *The Owner Cultivated Farm.*—In this method, the owner himself with the help of the members of his family, assisted when necessary by paid labour, cultivates his land. Cultivation by this method is always more satisfactory, provided the owner is not handicapped by insufficient finance.

(*c*) *Leased Farms or Tenant Farming.*—Land may be neither cultivated nor be supervised by the owner at all, but may be let out to tenants, who may actually cultivate the land or, if the holding is large, let portions to subtenants. Farming by tenants either the whole or part of one's holding is a system which is very largely in vogue, and it has both merits and demerits. For one thing land gets into the hands of the actual tiller of the soil who is helped in turn by the owner with money for purchasing manure, seeds or for special operations like weeding, harvesting, etc. It has the demerit that the tenant cannot feel the same enthusiasm as for the cultivation of land which may be his own and the cultivation is therefore half-hearted. Moreover where tenancies are for short periods the tenant has no guarantee of being retained and is averse to effect any real improvement. In the case of absentee landlords, the land is subject to serious neglect and deterioration.

Systems of Leasing.—The system of leasing may be (1) for a definite money payment at so much per acre or a lump sum for the whole of the holding; (2) the payment may be in *kind,* of a definite quantity of any one particular produce or more; (3) or a definite share of the produce obtained in the year. The first two kinds are generally found where there is much demand for land by tenants and the landlord is therefore in a position to dictate his terms more or less; the third obtains where tenants are few and there is not much demand for land. The lease consideration, whether money or produce, whether fixed or only a share in the varying produce of each year, is based upon a somewhat equitable basis and not fixed arbitrarily. It will be found on the whole to amount to one-half of the produce after deducting the expenses of cultivation, although it may not always conform to this principle. It is assumed that in the case of most crops the expenses amount to one-third of the produce, and hence one half of the remainder, *i.e.,* one-third of the total produce or a rough equivalent in money may be paid as the landlord's share. Many variations are come across in the share apportioned to either party, which depend upon local conditions, the nature of the crop grown, the expenses borne by each party by way of

manure, seed, land tax or assessment, milling charges (in the case of sugarcane), the right to grow subordinate crops, nature of irrigation whether flow or by lift, etc.

In Mysore, one-third is usual for ragi, jowar and other dryland grains; one-half for rice, one-half (all expenses split 50-50) or one-sixth and even one-twelfth for sugarcane according to circumstances, one-third in cotton and one-third in areca are approximately the shares which are common.

Friction, litigation and even violent agrarian troubles are incidental to tenant farming. Leaving aside questions of eviction, a frequent source of trouble is due to the fluctuation in the price of produce, tenants wishing to pay in kind when produce is low-priced and in cash when produce is high-priced, and agitating for a suitable change in the contract every time there is a marked change in prices. Generally as between the landlord and tenant local custom and the operation of demand and supply decide the terms and conditions, except where force is resorted to by either party.

Periods of Tenancy.—Tenancies may be renewable from year to year or running to varying periods as may be agreed upon between the parties. The longest leases, amounting almost to alienation, may be seen in the malnad arecanut gardens in Mysore. In such long leases the operations to be carried out in order to maintain and preserve the bearing capacity of the gardens, many of them very costly, are specified and enforceable against the tenant. Some tenancies though short are still for a sufficient period during which the tenant is able to reap the full benefit of the heavy manuring he may have given to any one of the crops, by utilising the residual effect for a following crop; in that case they are from three to five years, during which heavily manured crops like betel vines, plantains, sugarcane, turmeric, etc., may be followed by one or more crops of rice.

It is usual in some countries (as in Great Britain) to award compensation for unused or residual manurial value of the manures which may have been applied by an outgoing tenant (*vide* pages 173–74). In India also an outgoing tenant is entitled by law to obtain value for the permanent improvements he may have made, including the value of fruit or timber trees he may have planted and brought to bearing, based upon an agreed and prescribed rate of valuation. In the interests of the land, the tenant and even of the landlord, a comparatively long lease is preferable to those of short duration.

3. *Collective Farming*

This term has come much into use, after the system was introduced in Soviet Russia, where it is said to be working with remarkable success and with results to the State and the community which could not have been dreamt of in the days prior to the system. Though the idea conveyed by the term is simple enough,

the methods of collective farming are by no means so simple, especially as there are conflicting accounts published though generally of the rosy kind. At any rate as far as India is concerned no representative group of agriculturists has visited the country and studied the systems *vis-a-vis* Indian conditions and assessed their merits.

The highest or fully developed form of collective farming in Russia is that in which individual ownership of land is completely extinguished. "All the land is taken over by the State and becomes the property of the State and is attached to the Kolkhoz (collective farm) for joint cultivation. No land can be alienated by the Kolkhoz and a peasant's existence as an individual farmer comes to an end." The old boundaries are wiped out and land rearranged suitably for large farming and mechanised operations. Farming is completely under the direction of State experts, the forms of cultivation, seeds to be sown, manures to be applied, etc., from A to Z, being under their direction. The old owners become mere wage-earners and work as they would in a factory, even the shifting of the population to far-off places not being uncommon. All the hands are paid wages according to the work turned out, on a system of "work-day" units graded according to the kind of work. "For every day worked the member is credited with one-half to two work-days depending on the category and quality of performance. One peasant may receive only 12½ work-days credit while another doing a different job will receive 50 days credit, for a full month's work. At the end of the year Kolkhoz income and the grand total of days worked are calculated and the value of the work-day is determined by dividing income (after statutory deductions) by the total number of work-days. Each member is however granted a plot of ¼ to ½ a hectare for homestead and private use in gardening, poultry, bee-keeping and dairying, he being free to own one cow, two calves, two pigs, 10 sheep and goats, 20 hives and poultry and rabbits to any number desired." The income from this private farming belongs to the owner member.

The advantages of collective farming are (1) a large increase in the area available for cultivation, resulting from the removal of boundary ridges and the bringing under the plough of many individual vacant lots and of land left uncultivated on account of the distance from the village or other causes; (2) the possibility of using large-scale machinery like tractor ploughs, harvesting machines, threshing machines, winnowing machines and so on, all of which make it possible to farm a large area intensively and at the same time with the available labour alone; (3) the possibility of digging large or deep wells and the installation of suitable pumping machinery; (4) the use of better seeds, more manures and the adoption of better types of cultivation generally; (5) the keeping down of insect pests and diseases efficiently; (6) better storage of produce, and the substitution of an expert organisation with ample resources,

in the place of the whims and fancies or the poverty or unwillingness of petty individual owners.

Other Forms of Collective Farming.—It is clear from what has been said above that this complete collectivisation in Russia is based on force or the authority of Government to impose its will over the individual, although it is camouflaged under the name of "voluntary association". "The Government accomplished the task (compulsory collectivisation) by ruthless coercion. Relying on the poorest strata in the village, the landless, the horseless, the chronically starved; utilising their hatred of the village 'rich' and their longing for a better life; applying all forms of administrative and economic pressure—it succeeded in the task." The callousness and cold cynicism over this cruelty are brought out by the following revealing testimony of Bertrand Russel: "When I put a question to him (Lenin) about socialism in agriculture, he explained with glee how he had incited the poorer peasants against the richer ones, and they soon hanged them from the nearest tree—ha! ha! ha! His guffaw at the thought of those massacred made my blood run cold." (Bertrand Russel, in *Unpopular Essays*, page 219, on his interview with Lenin.)

Co-operative Farming.—Other forms of collective farming less drastic in method are also possible. These involve voluntary co-operation among farmers, in respect of one or more sets of operations; for example, in the co-operative ownership and use of machinery like tractors and tractor-drawn implements, irrigation pumps and engines, sugarcane-crushing machinery, threshing machines, spraying outfits and so on; the joint purchase and use of seeds of special high-yielding strains and of the various manures; joint operations in land improvement, erosion control; repairs to irrigation channels; joint marketing of produce; and even the voluntary consolidation of scattered fields or holdings into self-contained units of reasonable size. Co-operation may be practised all along the line or only for a limited number among them and the advantages of such restricted collective farming will vary in proportion. In Russia, as a matter of fact, many such forms have been tried and were abandoned only because the full advantages could not be secured except through complete collectivisation in spite of the ruthless coercion involved. These may however be referred to briefly:—

"(*a*) The early Kolkhozes generally took the form of simple co-operative societies (called 'toz') for the joint acquisition and use of complex machines (multiple metal ploughs, reaping machines, etc.). Land remained the property of individual owners who were 'toz' members, and the output of each parcel belonged to its owner. They were called societies for the joint cultivation of the land.

(*b*) Another method of collective farming was the agricultural 'artel'. Here the land, heavy tools and machines, farm buildings and work animals were held in common. Individual landholdings were lumped together, subdivided into fields according to crop and

worked collectively. The total output was divided among the members according to either labour or shares, or the number of consumers.

(*c*) There were finally the agricultural 'communes' which organised collectively not only for production but also for consumption. Members lived in communal homes with communal kitchens, nurseries, etc." (From *Management in Russian Industry and Agriculture,* by Bienstock, Schwarz and Yugow.)

All these have been scraped in favour of the complete and compulsory collectivisation.

In India too a period of experimentation will have to be passed through before any particular type of collective farming is selected as the one most suitable. The consolidation of the scattered fields and holdings will present an almost insuperable difficulty, complicated as it is by the laws of succession to landed property. The problem is however easier on new land thrown open for cultivation which may be cultivated much in the manner of the State farms of Russia or with suitable adaptations. An adequate development of industries will also have to go hand in hand with such collectivisation in farming, so that any surplus population resulting from the change-over may find employment in productive pursuits.

Experience of Co-operative Farms in Other Countries.—Co-operative farms involving varying degrees of co-operation and of several types have been working in some of the States of the U.S.A., in which the State plays a paternal role and pays much attention among other things to the betterment of the social welfare of the members. In the newly-formed Jewish settlements in Palestine likewise co-operative farming has been largely attempted. In all these types of co-operative farming the voluntary principle is the distinguishing characteristic, as against the Russian collectives which are based upon compulsion. These farms cannot be called successful in all respects; but they will in any case afford valuable guidance for experiments in India or elsewhere. It is notworthy that a tendency is said to be noticeable in many co-operative farms for the settlers to look upon them as more or less stepping-stones to an eventful acquiring of a separate self-owned farm. Whether a purely voluntary form of co-operative farming will survive this strongly implanted human motive of ownership of property, the feeling indeed of "mine" as apart from "thine", is a very relevant question. Soviet Russia has of course answered it in an emphatic negative, and resorted to compulsion. We cannot however go into this subject further and deal with it in all its economic bearings.

SELECTION OF FARMS

In the selection and purchasing of new land for farming or of farms or land already under cultivation, certain general principles should be kept in view, whatever may be the kind of farming or cropping that may be proposed to be taken up. They are the following :—

1. *Climatic Features.*—The rainfall and the general climatic conditions of the tract should be favourable, the annual rainfall being adequate and well distributed. The general level of agriculture in the neighbourhood and the health of the community will give a fair indication of the land or situation in this respect.

2. *Topography.*—The situation of the land, whether in a hollow and badly drained flat or on a steep slope liable to erosion and requiring considerable expenditure in terracing and the like, or on fairly level ground, should be looked into. Under Indian conditions land situated in valley bottoms and somewhat low lying is not a great disadvantage, as it may be considered to be elsewhere. Such land in India may be convenient for the sinking of wells or of impounding water, which are both all-important considerations in this country. Land on steep or even moderately steep slopes will be always subject to soil erosion, to considerable sheet erosion if not to the formation of deep gullies. Erection of cross dams, terracing and frequent repairing will be required, all involving much expenditure. Tillage operations are also more arduous, the soil is subject to wash, exposing more and more gravel, which will have to be picked up and removed periodically; in fact farmers describe such land 'as growing gravel' which is a very expressive description. High lying land is also likely to be wind-swept open country needing protection by means of wind-breaks of some kind. Land on the level, or a very gentle slope, or land fairly level at the bottom of valleys should be preferred, in the ascending order of excellence.

3. *The Nature of the Soil.*—The nature of the soil is an all-important matter. It should have sufficient depth, and trial pits here and there over the site will disclose the depth as well as other features of the profile. Both colour and texture should be uniform at least for a depth of 18" to 24"; the colour should be red, reddish, dark red or black or different shades of black or dark grey. The texture should be moderately loamy, or heavy loams. Any large admixture of coarse gravel, stones and rough particles will have to be avoided, as likewise highly sandy soils or soils with positive defects like alkalinity or raw unweathered clays which can be made out by the colour, such as whitish, greenish or with streaks of light blue, etc. White incrustation on the surface and black bare patches mean alkalinity in the soil and these will have to be avoided.

The condition of the vegetation on the land (if new) will be a useful indication of the fertility of the soil, luxuriant growing trees or abundant shrub growth signifying a good soil as against struggling stunted vegetation; a bare surface with not even grass on it is a bad feature and will need further careful examination. A soil chemist may be consulted advantageously, in case the land to be taken up is large enough to justify such technical advice.

4. *Prospect for Well Cultivation.*—The chances of striking water at a fair depth for purposes of irrigation wells will have to be examined, as nothing contributes to the success of farming as a

regular and reliable source of irrigation, however small it may be. In this matter also the neighbourhood will afford useful indication regarding depth of wells, nature of the supply, etc. (see also pages 91–102).

5. *Other Irrigation Sources.*—Closely connected with this matter is the need to find out if the land is commanded by an irrigation source such as tank, canal or river and, if so, what area of such land could be depended upon. One could do with a much smaller area of good irrigated land than may be the case with dry or rain-fed land. In the case of irrigated land the situation must be such that there will be no obstruction to water or difficulty in draining or any danger of submersion, all of which are traps to be looked for when wet land is offered for sale.

6. *Road Service.*—The accessibility of the land or farm should also receive consideration, that is to say, if it abuts on a good road or is reached by a road, which is common to all the villagers. The question of right of way will sometimes present serious difficulty and may have to be purchased at a big price and after much trouble. A good road connecting the farm with the main highway is a great and obvious advantage, in many respects.

7. *Availability of Labour.*—Attention should also be paid to the ease with which labour can be secured in the neighbourhood. Difficulty in this respect often puts out of the question many localities which may be otherwise very eligible. The need for importing labour from a long distance should be avoided as much as possible. In this same connection the health of the locality is an important consideration, as labour may be unwilling to serve and desert the farm, and for good reason, if it is subject to malaria or other diseases. In regard to labour a friendly neighbourhood is a great advantage, just as a hostile one is a serious hindrance; it will be well to have some assurance beforehand that friendly co-operation will not be withheld.

8. *Proximity to Market.*—The proximity to towns and large markets is a great advantage, for obvious reasons; but the advantage may be bought at too great a price especially in these days of quick motor transport under which distance is not such a great deterrent factor as it used to be formerly. Nevertheless the advantage of nearness to towns will be felt in many ways and should be aimed at in the selection.

9. *Forest Land.*—Sometimes forest land becomes available in fairly large stretches when forests are thrown open for cultivation. Such land is likely to be generally very fertile being virgin land with much fertile top soil. It will however have to be closely surveyed, in the interior as the area is jungle-covered and the nature of the surface and of the soil may be all shut out from view, and ravines, marshy hollows or large stretches of rocky outcrops and boulders may exist, which will seriously reduce its value for cultivation. Very heavy tree growth will also have to be cut and removed and even

after clearing, the large tree roots will be a hindrance to proper tillage for many years. The menace of wild beasts, both large and small, to men and bullocks and to many crops as well, is also to be reckoned with. In villages close to jungles wild pigs, jackals, deer, porcupine and other animals commit great havoc, and watch and ward and protection by strong fencing are all very essential. In selecting land in such situations or buying farms in such villages, it is necessary to balance these considerations against any tempting offers in regard to price or other matters.

10. *General Features and Revenue.*—It is also usual in the case of ready-made farms or plantations to look to the various general features like the residential buildings for the managers and labourers and offices, stores, factories, tanks, wells and other water sources and rights thereto and the age and general condition of the plants. In addition, above all, the yielding capacity of the farm or plantation and the revenues derived from it over a series of years will have to be looked into. Farms of this kind, other than the plantations, do not exist in India. A very near approach is the so-called *jodi* or other proprietary village which is owned by one man who keeps some portion (generally the wet land) as the home farm to be farmed by himself with or without tenants, and who lets out the dry lands to the villagers on a more or less permanent lease. Such villages are also owned by a group of shareholders who are descendants of the original owner, and who may be only absentee landholders. The days of such farms or villages seem however to be numbered as they will soon be extinguished as one-man holdings and be parcelled out to the actual tillers of the land.

CHAPTER XXV

SOME ASPECTS OF CROP HUSBANDRY AS A BUSINESS

IN the foregoing chapters crop husbandry has been dealt with from the point of view of the actual production from the land, the factors which are responsible for increasing the quantity produced and the factors which operate in the reverse direction. Crop husbandry has however another important aspect to it, *viz.,* the financial or business aspect. The success of farming of whatever kind it may be, depends not merely upon the quantity of the output per acre, the number of tons or bushels produced per acre but to a large extent upon the net profit earned, upon the extent to which the expenses of crop production, and the cost of living of the farmer were met and a surplus left over and above this expenditure. It is true that in the large majority of cases in India, farming is only on a bare subsistence level and can hardly admit of being treated as a business. It is also true that even in the case of the better class of farmers, if all the costs are reckoned that is, if judged by ordinary standards of business, the net returns may be practically nil, which indeed is proverbial in this country. Nevertheless farming, whether carried on merely as a means of subsistence or as a commercial undertaking, is a business and it will be useful in the one case and quite necessary in the other that the general principles of management should be understood and adopted to the extent possible.

SOME SPECIAL HANDICAPS OF FARMING AS A BUSINESS

Although as a business farming or crop raising has much in common with other forms of enterprise such as those connected with production, transport or distribution, it differs from these in some important respects.

1. *Uncertain Returns.*—In the first place it is subject to the risks of failure or uncertain returns owing to causes beyond the control of man much more than any of the others. The influence of weather conditions such as rain, drought, winds and storms, frosts, etc., is very great and at the same time such as cannot be foreseen or guarded against. Crop pests and diseases form another important factor of the same class, and though they can sometimes be prevented or their incidence mitigated, are still in a large majority of cases very destructive and cannot be successfully combated. Both these two kinds of factors bring about a very material reduction in the yield and make it almost impossible to forecast the outturn that may be expected. This feature is in sharp contrast with other enterprises where the output is definitely known and where risks due to strikes, lock-outs or 'acts of God' are of rare occurrence and can, at any rate, be successfully overcome by suitable methods. This uncertainty of the production and the consequent upsetting of many arrange-

ments is a peculiar and unavoidable feature of crop raising as a business, which makes it difficult to apply strictly business principles in all its aspects.

2. *Delayed Returns.*—Another serious drawback from which crop raising suffers as a business is that a long period of time of about six months or even a whole year has to elapse before a return can be expected for the factors of production expended on it. Whereas in other enterprises, returns are being earned every day and indeed every hour continuously in many cases, and the time interval between the stage of raw material and that of finished product is only a question of a few hours, or whereas in the case of a mining enterprise returns accrue continuously or as in the case of road rail or ocean transport, likewise during every minute that the wheels or paddles keep turning, in crop raising one has to wait a whole season or a year for the return to accrue. There are absolutely no means of speeding up the returns.

Two important consequences follow from this feature, both of which operate as a great handicap to agriculture: (*a*) The first is that when capital is borrowed for working expenses neither capital nor interest can be paid back until the produce comes in and can be sold, that is, until some six months or a year after borrowing. If the rate of interest should be exorbitant, then too heavy a burden is imposed on the business and any surplus earned may be swallowed up by these payments. A comparatively long-term credit is therefore required for agriculture, during the course of which no payments of any kind can be made towards capital or interest, in great contrast with other enterprises in which returns are continuous and this undue burden can be avoided.

(*b*) The second relates to the uncertainties of the market for the produce, that is to say, to the difference between the price for produce ruling at the time the crop was put down and that ruling at the time when the produce is harvested and is ready for sale. In respect of many annual field crops like cotton, groundnut or sugarcane, etc., the price at the sowing time may be high and tempting and a large area may be sown, in the hope that such prices may continue; serious disappointment however may have to be faced when it is found, as it is not unusual at all, that by the time the produce from the sowings is harvested and comes to market prices have tumbled down and returns are much below what was anticipated, on the basis of which expenditure was incurred. When capital has been borrowed for the year's operations this circumtsance makes the handicap doubly serious.

3. *Slack Season in Farming.*—As a business, farming also suffers from the fact that for a good portion of the year, sometimes about six months, there is either a cessation of work on the farm or at least a large measure of slackening. As far as productive work is concerned, this enforced leisure implies, strictly speaking, a loss of labour income for the farmer and his permanent labourers, which

has to be allowed for in reckoning the total income or return from the business. In tracts which depend solely upon the rainfall and only dryland cultivation is possible and in villages where even though irrigation may be available only one crop is raised, and the land has to lie fallow for the rest of the year, this kind of a slack season is an unavoidable feature. It can be mitigated only to the extent that a combination of irrigated and dry cultivation is rendered possible or, better still, a combination of some permanent garden cultivation as well. In the large majority of cases however no such combination exists nor indeed is possible.

4. *The Operation of the Law of Diminishing Returns.*—Crop husbandry is also subject to the operation of the law of diminishing returns to an extent more prejudicial to it than in the case of other forms of production. In fact, it is from the experience in crop raising in regard to returns as related to the factors of production that this result of observation has been found to operate as a law and applied to other enterprises also. No additional investment of capital, more irrigation, more manure, more labour, etc., can increase the yield in proportion. On the other hand, in agriculture any such increase beyond the correct limit may prove even harmful and cause diseases, scorching abnormalities, etc., all of which bring about a reduced yield. Beyond a limit, no displacement of human labour by labour-saving machinery, no mechanical improvements which can multiply production several fold, no increasing of labour, and no working in day and night shifts and stretching the hours of work thereby, which are well-known methods of increasing production in other enterprises, are applicable to agriculture. The main reason is the obvious one, that in agriculture we are dealing with living things like plant life and not with lifeless material like mined or manufactured articles.

5. *Unfavourable Marketing Features.*—The next peculiar drawback of crop raising as a business relates to marketing. Although many of the features in marketing which operate prejudicially on the producer are common to both agriculture and other forms of production, there is greater scope for their operation in agriculture on which they may be said to press more heavily than upon the others. The chief reasons for this difference are (*a*) the smallness of production by individual producers, which necessitates their selling to only petty or comparatively small traders or middlemen of many grades; (*b*) the need to sell produce as it is gathered, without being kept or stored for any length of time, because produce is too bulky and the farmer has no storage accommodation, that he is moreover in urgent need of money for repayment of advances, debts or other dues and also because some produce like fruits, vegetables, etc., are perishable and cannot be stored; and (*c*) the lack of organisation among producers, which is a feature of even advanced countries and in India, acts as a very serious handicap.

Reducing the Cost of Production

The above being the special features which distinguish by their prejudicial operation the business of agriculture as distinct from other enterprises, the general principles which underlie the success of any kind of productive enterprise may be said to apply to it equally well. These have broadly two objects in view, one being complementary to the other, *viz.*, (1) to bring down the cost of production, *i.e.*, to produce at as low a cost as possible; and (2) to secure as high a price as possible for the article so produced. 'Produce cheap and sell dear' is a business maxim, which applies to all enterprises. The first concerns the 'production' side and the second concerns the 'marketing' side of crop husbandry, both of which may now be dealt with in some detail.

The elements which enter into the cost of production are (1) the working capital; (2) the cost of the various articles which have to be purchased like seeds, manures, implements, carts and bullocks and other items of equipment; (3) labour. The more cheaply one or more or all of these can be secured, the less becomes the cost of production, other things being equal and under normal conditions. The various handicaps like bad seasons, diseases and pests which neutralise the production factors are of course left out of consideration for the moment.

Capital.—In addition to the peculiar difficulty that a return on the capital accrues only after the lapse of a whole season, the methods of raising or obtaining capital are also such as make this handicap still more severe. Capital for working expenses and for the needs of the family till the produce comes in is usually obtained by borrowing from petty money-lenders, generally at an exorbitant rate of interest, because the amounts required are small and are sought at frequent intervals. The money-lender is in most cases also a trader who sells to the farmer many of the articles he may be in need of and who is also a buyer of whatever articles the farmer produces. This kind of relationship is found convenient in practice to the producer but he pays a very high price for this facility. It has been found a very difficult matter indeed and almost an impossible one to wean the farmer from this connection and divert him to a more desirable source. The banker-*cum*-trader sells at his own price and also buys at his own price and although he gains at both ends at the expense of the producer the latter cannot help stepping into his parlour and the connection once established is hard to break. It is also possible in this arrangement, should the worm turn, to camouflage an exorbitant rate of interest by more than its equivalent in the sale and purchase side of the transactions with him. Where capital or interest is to be paid back in the shape of produce which is also a common practice, the rate of interest will be found unconscionably high. Even in the case of large producing concerns like the planting industries for instance, the banker is often also a trading firm selling

plantation requirements of all kinds and buying the whole production however large it may be. Here also the producer ceases to be as free an agent as may be desirable, and the capjtal will be found to have been secured at a very high price. The remedy lies only in the co-operative movement, by which producers can have their own organisation not only for securing working capital but also for various other important purposes as will be referred to below. The method however is very difficult in practice and it is easier to suggest than to carry out; but this is about the only course open to the producer, by which he can materially reduce the cost of production in this particular respect.

Cost of Purchased Articles.—The next important factor in the cost of production is the need for purchasing several farm requirements. Leaving aside the initial equipment like carts, bullocks, implements and such items, and taking only articles required for the season and the particular crop, the principal ones are manure, seeds, bullock feed, spraying materials, fuel oils, lubricants, etc. In respect of seeds, farmers usually set apart and preserve a sufficient quantity from the year's produce for the following season, and it is only when there has been a crop failure or when a change of seed is thought necessary that seed grains are purchased. In respect of sugarcane, potatoes, ginger, turmeric, onions, plantains, etc., seed or planting material is mostly brought. Some of these like ginger and potatoes are very expensive. In the event of a failure or low yield the high cost incurred for seed will be a crippling burden. In such cases one has only to look to care and skill in every detail of the cultivation and to a good yield for off-setting this item in the expenditure.

Manure on the other hand is always a purchased article. No farmer gets sufficient cattle manure from his own animals for adequate manuring and even cattle manure therefore has to be purchased. So likewise is green manure for the cultivation of rice and the other manures, both bulky and concentrated, like oilcakes and the chemical fertilisers. Such purchase entails very heavy cost, but as production in a large measure depends upon and can be materially increased by adequate manuring, this expenditure is indispensable. If this expensive factor in the cost of production is to be kept low, then both technical knowledge and business ability are required. On the technical side, the best method of turning every waste product on the farm or cheaply obtainable material into composts and other forms of manure should be adopted and the supply increased with the minimum of cost in money, and the loss or waste of fertilising elements scrupulously avoided. What has been said about the role of the different plant foods, the nature of the manures required for different crops, the unit values and other factors which decide their comparative merits and the various other aspects of manuring explained in the chapters on "Manures and Manuring" should be applied in selecting the manures to be purchased and their quantities. In this way it may be possible to purchase more economically than

otherwise and, if combined with some business acumen such technical knowledge will be found even more helpful in effecting economy. The same observation applies to the buying of spraying materials, where these may be found necessary. If Farmers' Co-operative Manure Supply Societies should be formed for the stocking and sale of these materials to members and managed efficiently, then also considerable saving can be effected than by buying from the ordinary trader.

Cost of Labour.—The cutting down of labour costs is perhaps the most important method adopted for the purpose of bringing down the cost of production in any enterprise, and nothing is a more common feature in industries of all kinds than the continuous flow of inventions designed with the object of increasing the output per individual or the displacing of as many hands as possible. What applies to other enterprises applies to crop production as well and the producer has to be keenly alive to the need for such reduction in the cost of labour by similar methods, and the adoption of labour-saving machinery in every farm operation. The man with a rake is proverbialy at an advantage over the man who has only his bare unaided hands to work with. Whether it be merely tools for manual labour or for bullock labour or for mechanical power, it should be the constant endeavour of the farmer to equip himself in such a manner that his labour costs are cut down to a minimum. Machinery has the great advantage that it can speed up work and this is very important in agriculture where operations have to be conducted and finished within the proper time or season.

There are cases of course where human labour is so cheap that the use of machinery may not result in a saving of labour costs and also cases where the nature of the work may require the thoroughness which human labour alone can effect and may be therefore indispensable. Mechanical equipment however is making continuous progress and can be had of many kinds and suited to a variety of conditions and the kind appropriate to each particular condition will have to be selected and used. In the previous chapters some of these have been referred to already and only the general principle need be emphasised here.

Cost of Labour and Mode of Employment.—In ordinary agricultural operations the cost of labour in any particular kind of work may be to some extent modified by the agency employed to do it. For example, the work may be performed in one of two ways, *viz.,* (1) solely by the farmer and his family and with help from neighbours without the payment of any cash wages, or (2) by the employment of paid labour, both permanent and casual or temporary.

In the first method under ordinary village conditions there is considerable co-operation among villagers, so that each works for the other and thereby gets through the work expeditiously and without having to make cash payments. Whether aided by mutual co-operation or not, in this system where the farmer himself works on his

field the work is done thoroughly and the quality of the work is high. Of course such a system is suited only to small holdings. When paid labour is employed it may be either permanent or temporary or more generally both. In the former case, it is important to see that there is full work for the men employed, so that there is no lost time and that the employer gets full value for his money.

When temporary or casual labour is employed it may be by the day, by the piecework system (or the amount of work done) or by contract. In all these there is always the drawback that the work may not be as thorough as may be desirable, unless it is well supervised or unless the farmer himself also works along with the men, as he sometimes does except when the work is given out on contract. Where men are employed by the day the main drawback is that they may idle away part of the time and that close supervision is needed to prevent it. The piecework system is free from the fear that the men may idle away the time but the quality of the work may not be quite satisfactory unless this too is closely supervised. It is moreover the case that all kinds of farm work may not be found suitable for being carried out on the piecework basis. In any case both the piecework system and the day work system will require close supervision and preferably that the farmer himself works with the men.

The next method is the contract system. This system will be generally found most convenient and eminently suitable in all but the very small farms. It will relieve the farmer from the task of finding and retaining the necessary labour force and the trouble of constant watching. Whatever system is adopted it will be necessary and a great advantage, if the person who supervises the work is thoroughly acquainted with the details of the work, especially in what particular ways it should be thorough and in what particular ways it is likely to be scamped without detection.

Method of Payment of Wages.—The form in which wages are paid may also influence the cost of production in respect of labour. This applies mostly to the harvesting and threshing of grain, the picking of cotton, the digging and gathering of groundnuts, the picking of fruits, etc. It is sometimes the practice to settle the wages as a particular fraction of the quantity of the produce picked or gathered. Depending upon the heaviness of the crop as in the case of a crop like cotton or the difficulty of digging in the case of groundnuts, the proportion is fixed equitably. If the crop is very heavy (as, say, in the first picking) workers may be satisfied (or used to be) with a sixth portion of the day's picking, the fraction going up to a fourth or a third in the subsequent pickings. This system results in somewhat expeditious work and avoids the need for the farmer to borrow money for cash wages. A further incentive to quick work is sometimes given in the shape of premium for quantities picked over and above a specified minimum, either as a

small money wage or a larger share in the produce, for this excess picking.

Many kinds of operations like the transplantation of rice, harvesting of rice, harvesting of groundnuts, the digging of the black cotton soils, husking, slicing and curing of arecanuts are done by contract labour and gangs of men and women migrate during the season to the tracts where such work is to be done. There are also professional contractors who equip themselves suitably (as in the case of sugarcane milling and jaggery boiling) and gangs of navvies for the digging of black cotton soils, who undertake such work on contract and whose services are largely availed of conveniently.

The cost of operations like areca curing, cane milling, tobacco curing, etc., and the trouble attendant on the work are avoided sometimes by the system of selling the standing crop. The producer is also saved thereby from losses arising from theft, deterioration and the risks of price fluctuations. The choice of any one particular method in preference to another will largely depend on the exigencies and needs of the farmer and upon local custom, and on the whole the sale of the standing crop where possible will be found very convenient in practice. Bargains are generally so well struck that neither party gains any large or unreasonable advantage over the other, except when prices rise or drop violently between the time of the sale of the crop and that of marketing it in a prepared condition.

Mutual Help among Farmers.—Neighbourly co-operation among villagers to which reference has already been made is certainly the best method by which the farmer can keep down the expenses of much labour on the farm which will otherwise have to be paid for in cash wages. Admirable customary practices can be seen in many villages in regard to ploughing, reaping, sugarcane milling, irrigation from riverbed percolation channels, fencing of areca gardens, etc., on an efficient and equitable co-operative basis, but for which the work cannot be done so expeditiously or at such little or no cost in money. It will be a great advantage if the principle can be extended to the ownership and use of mechanical appliances like pumping plants, threshing machines, power-driven sugarcane mills, tractor ploughing outfits and so on. There is indeed no other practicable method of introducing these improvements and of enabling the Indian farmer to benefit by their undoubted advantages. In many countries with similar small holdings and scattered fields such as France, Belgium, Holland, Denmark and the Channel Islands, it is through co-operative ownership that farmers are able to use machinery, which will be too large and too costly for individual holdings or ownership.

Reducing Costs through Increased Production.—The cost of production can also be reduced by securing a larger increase in the yield per acre or making the land a more efficient producer. Such reduction in cost is of course relative to the quantity produced, that is to say, the cost per unit whether by weight or volume. Though

with a larger production the total or absolute cost will be higher than for a smaller yield, the cost calculated per maund or bushel will be less. To this end all factors of production are to be provided and employed up to the optimum; the field has to be prepared thoroughly, heavy and proper manuring given, the best variety sown, timely and ample irrigation given, pests and diseases kept down by spraying and other methods and so on. The law of diminishing returns will of course operate, as mentioned already, but there is a great deal of room for the increasing of the yield and there is hardly a crop at present where the point of economic optimum may be said to have been reached, and further expenditure on these factors can be deemed inadvisable. Even in advanced and wealthy countries like Great Britain, for example, where crops are not subject to the risks of failure to anything like the extent that they are in India, it is stated "As the farmer increases his efforts, so his returns increase up to the point where the inevitable diminishing return sets in. Where this point lies we do not pretend to know, but *we cannot admit that it is yet* reached." (*Rural Report of the Liberal Land Committee,* 1923-25.)

Moreover where the returns are reckoned by their money value, then what may be considerred the optimum at one price level, may cease to be such at a higher price level and a higher expenditure on the factors of production may be permissible. Conversely, in the event of a drop in prices and at a lower price level, the old optimum may recede in the opposite direction and part of the expenditure incurred will have to be considered unremunerative. Such a risk is unavoidable, but in the long run the wisest course for the producer will prove to lie in making his land produce the maximum it is capable of.

In any case, one of the recognised means of reducing the cost of production is the securing of a larger yield per acre and the principle has to be borne in mind. Low rainfall and other adverse seasonal conditions and the incidence of pests and diseases largely upset calculations in Indian agriculture, but under normal conditions the principle applies.

Crop Insurance.—In some countries it is possible to insure crops against damage by hail, frosts, cyclones and other visitations, as there are regular Insurance Companies which undertake this kind of insurance. In regions which are liable to such occurrences and to serious crop losses on that account, it will be a wise and prudent measure to insure them against such loss. Although in a normal year, such expenditure adds to the cost of production and does not reduce it, still in the long run it will, like all other forms of insurance, prove really a saving, and money expended in the shape of the annual premia should be considered money well spent. In a country like India where crop failures or reductions of varying degrees are a regular feature in dryland cultivation and the uncertainty of the rainfall is one of the certainties of the business, some form of crop

insurance which will guarantee a minimum yield is a very desirable measure and will perhaps be introduced before long. Some of the important permanent crops like the fruit trees are subject to periodicity in bearing, a year of poor yield following one of a good yield; others like the mango are subject in addition to serious and unexpected loss by the prevalence of heavy mists during the flowering season or by the incidence of the mango hopper pest or by high winds and thunder-storms when heavy with fruit; sugarcane is frequently damaged seriously by cyclones in the cyclone belt of South India. These and many others can with great advantage be insured, if a system of such insurance should come in. Insurance is a recognised method of avoiding heavy loss in any business and the principle applies to crop raising as well.

Selling at a Higher Price or the Marketing of Produce

Next to reducing production costs or producing at a lower cost per unit, is the securing of higher prices for produce in the market. Producing cheap and selling dear is as already mentioned, the essence of successful business and the measure of success is the extent to which both operate in the desired direction or are complementary to each other. The elements in the cost of production and how each can be cheapened having been dealt with above, we shall now deal briefly with the marketing side of the business of crop husbandry.

1. *Quality of the Produce*

Other things being equal, the better the quality of the produce, the higher the price it will realise, and efforts should therefore be made to put on the market produce of the best quality. Quality comprises many elements, such as cleanliness, freshness, purity of variety and grade, freedom from adulteration or other tempering and in general the presence in a high degree of the particular feature or component in the article for which it is esteemed.

(*a*) *Cleanliness.*—The need for cleaning produce before sale or storage has already been referred to. Such cleaning will remove admixture of sand, grit or earth coming from the threshing floor, chaff, bits of straw, leaves and stems and to some extent immature or light grains, most of which are removed by thorough winnowing and sieving. Further cleaning may also be resorted to by garbling or the picking out of broken bits, discoloured or bleached portions which can be easily made out by the appearance and which, if present, will reduce the price. Cleaning may sometimes be done during the picking of the crop itself as in the case of cotton, where stained, weevil attacked and immature bolls can be picked separately from sound cotton.

(*b*) *Freshness.*—Freshness in produce is another attractive feature, just as mouldness or bad smell indicating age or damage in storage, and in the case of fruits and vegetables a dry shrivelled or wilted appearance, are the reverse; the one of course tends to put

up prices while the other tends to depress prices. All storable produce has to be thoroughly dry. A common drawback (sometimes the result of deliberate fraud) is a high moisture content in the produce due to insufficient drying or to exposure to damp or rain after good drying. Such moisture lowers the price and when it exceeds any specified margin entails also a heavy penalty. Groundnuts, cotton, tamarind, tobacco, chillies and even the ordinary grains sometimes are subject to this drawback.

(*c*) *Purity.*—Purity or freedom from mixture is another important element. By this is meant that the whole produce belongs to one variety or strain and is not a mixture, however small it may be. Where many varieties exist and are under cultivation, there is much room for such admixture, chiefly because the seed itself was not as pure as it should be when sown. Red grain in a golden variety or round and coarse grain in a lot of fine grains, pulses with seedcoats of different colours, local cotton with American or other cotton varieties, mixed lots of Spanish, Japanese, Mauritius or other varieties in groundnuts, etc., are examples of such mixture. The way to avoid such mixture is really at sowing time, when the seed has to be scrupulously clean. After harvesting, the separation of the mixture becomes either impossible or too expensive. Where two or more varieties are grown separately, then they will have to be harvested, stacked and threshed separately, the threshing floor being scrupulously swept and cleaned after each variety is threshed.

(*d*) *Grading.*—Produce should be graded into different grades or sorts where it will admit of such grading, and the grades may be marketed separately, instead of sending it in a bulk lot and leaving the grading to be done by the trade. Such a procedure will generally result in a larger money return for the total produce than if it were sold ungraded. Many articles are sorted according to sizes and this cannot be difficult for the producer himself to carry out. In the case of fruits of all kinds, vegetables, potatoes, eggs, etc., such grading is quite easy and although many sorts may not be elaborately attempted, even a grading into, say, three sizes, such as large, medium and small, can be easily managed, each comprising a particular range of sizes. In many crops the trade itself recognises several standard grades; in coffee for example, such as peaberry, extra bold, A, B and so on, the separation being done by means of appropriate screens containing holes of definite diameters. In tobacco a very elaborate system prevails by which the cured leaf is classified and sorted, the principle being the colour, texture, soundness of leaf with varying degrees of blemishes, etc., all giving rise to several grades. In arecanuts likewise (in Mysore) an elaborate classification exists in the trade, but the separation is quite easy and can be done by the grower himself, if he chooses.

Under the Agricultural Produce (Grading and Marking) Act, 1937, statutory recognition is given to approved qualities or grades, which can then bear the AGMARK. This grading has been introduced

in respect of several kinds of products, and the producer can, if he chooses, grade according to this system, but it is mostly suitable where large quantities are handled as in the case of large wholesale merchants. As this is a standard and well-recognised quality, it commands a wider market, and proportionately better price.

2. *The Holding up of Produce*

Normally, prices rule rather low immediately after harvest when every one brings his produce to market and the supply therefore is very large. Such abundant supply and the rush and eagerness to sell naturally lead to a slump and although there may be no slackness in the demand, prices are generally low. On the other hand as the months go by, the inflow of produce diminishes and prices consequently steadily rise, until the peak is reached usually towards the close of the year, somewhat before the next harvest is due. Stocks in the market are almost exhausted, supplies are unable to meet the demand and therefore prices go up. This is a normal feature of marketing and the producer should try and utilise it to his advantage as much as possible, by holding over his produce for as long a period as he can and then only to bring it for sale, or in the alternative to market it in instalments at desired intervals. To the large majority of farmers this course may not be possible, as the need for money is usually pressing and the only way to meet it will be the prompt sale of produce. If Co-operative Farmers Unions or Marketing Societies come into being then the member producers may be able to obtain an advance on their produce, reserving the sale and final adjustment to some future date, when prices may be better. Produce can in that way be stored and sold only after the rush ceases and prices go up. In normal conditions such prices may be high enough to cover interest and storage charges and leave a margin of profit. The risk of a fall in prices during this time and loss or at least the lack of any special advantage by such storing and delayed sale is not altogether excluded, but the chances are very much more against such risk than in favour. In fact, when sales are made to the merchant in the usual way he always banks upon this chance and is seldom disappointed.

3. *The Elimination of the Middleman*

In the ordinary marketing of produce, in its transit from the producer to the consumer whether the latter is the manufacturer buying raw material or members of the general consuming public, the produce passes through several hands or agencies, each of whom performs a definite function and has to be paid for his services. These charges have to come out of the price paid to the producer, as a selling commission but are mostly passed on to the consumer. The result is that the price which the consumer pays for the article is very much more than what the producer received for it. There is always a large difference between these two prices in every class of

produce; in some it may be very large, in others moderate and in rare cases rather low, compared with the service rendered. It is one of the aims of agriculturing marketing to eliminate or reduce the number of these agencies or 'middlemen' and to contact the producer directly with the consumer to whatever extent this may be practicable.

Middleman's Functions.—The need for a number of middlemen and the service they perform will be understood if we examine the present system of marketing closer. There are two phases in the business of marketing, one being the collecting together into the hands of large central buying agencies of the produce from the innumerable producers scattered over the country which is called the "assembling". From these assembling houses the produce has to be made available to the consumer, either abroad or within the country itself. The former, called the 'external' market is however not comparable with the 'internal' or home market in India although in itself it is large and estimated at Rs. 200 crores as against Rs. 1,000 crores of internal trade. Leaving aside the former, which is shipped abroad in large bulk, the produce in the market has to reach the consumer down several steps, this phase being called the "distribution".

'Assembling' Produce.—While in the "assembling" process, produce moves *up* in several steps through successively larger middlemen, each one handling more and of a higher financial status than the one below him, in the "distribution", the produce moves *down* in several steps, through middlemen, each of whom handles a smaller quantity than the one above him and being also of a lesser financial standing. In the 'assembling' side there may be, for instance, (1) the petty village merchant who buys whatever small lots are brought to him; (2) the itinerant trader who buys direct from the producer and goes from door to door (doing sometimes some bartering of goods) and also from the village petty merchant whatever he may have collected; (3) somewhat larger traders who go from one weekly fair (*santhe* or *hat*) to another regularly and buy whatever may be brought in; (4) the brokers and their travelling and touting agents in the large *mandies,* who arrange for the sale of farmers' produce, which is brought to them by the farmers themselves, direct or through touts; (5) the large merchants themselves who bid at the auctions held by the latter brokers, or the brokers themselves who may do some buying and selling on their own account; (6) the emporiums or large warehouses of wholesale merchants, who sell to the exporting firms (in the case of external markets) or hold it up for the distribution phase of the marketing.

The most important assembling stage is at the *mandies,* to which farmers directly cart produce for sale. These various agencies charge not only brokerage, but various handling charges, godown rent, tools and customs in transit, and several petty imposts according to local custom. In the case of jaggery, for example, these

different charges debited to the farmer (seller) per Rs. 100 worth of jaggery amounted from a maximum of Rs. 9-2-0 down to a minimum of Rs. 1-10-0 while in certain markets the broker levied in addition from the buyer from Rs. 3-15-0 to Re. 0-1-9 (*Report on the Marketing of Sugar in India,* 1943). More or less similar charges are to be incurred in marketing other kinds of produce also.

Distribution of Produce.—In the second or 'distribution' phase during which the assembled produce travels down to the consumers, the market has many grades of middlemen. Commencing from the large wholesale supplier who has purchased the assembled produce, there may be sub-wholesalers, district agents, town merchants, petty shop-keepers, market retailers, itinerant vendors or basketmen who go from door to door, street corner booth vendors, who buy successively smaller quantities, or different grades according to the consuming market to which each caters. Each therefore meets a special need and convenience and all of them help in the aggregate to find a sale for all the produce from the choice to the culls. Each of course has to be paid for his services and such charges are only passed on to the consumer, to whom the appropriate increased price is charged, or if it is an article which is sold at a uniform price, the wholesaler includes a very big commission which is distributed in a graduated rate to all the retailing agencies down the ladder. The net result is that there is a large difference between the price received by the producer and that paid for the article by the consumer.

Marketing Charges and Prices of Some Articles.—In the accompanying statement which was compiled from the Government of India Marketing Survey Reports, is given the information relevant to and illustrative of what has been described above, in respect of eight different kinds of produce.

To eliminate the middlemen and turn over the saving so effected partly to increase the price paid to the producer and partly to ease the price charged to the consumer is the obvious means of benefiting both and is generally recommended in the interests of the producer. In practice this is found to be a counsel of perfection and most difficult to achieve; for one thing each middleman performs a distinct service, whether mere bodily service, or finance or the undertaking of risks, all of which have to be paid for. It is only where the charges payable to one or the other becomes unreasonable or exorbitant or where organised trade exploits a needy and ignorant mass of producers bereft of any organisation that such a course becomes a crying necessity, though even under normal conditions it may be desirable and advantageous to the producer. Such elimination in part at least can be secured only through the starting of large Co-operative Farmers' Unions or Societies for the sale of produce.

Properly organised and worked such societies can attain remarkable success not only in affording relief to both producers and consumers but even to the extent of making them a power to be reckoned with in the trade. In addition to the efficiency in manage-

Statement Relating to Marketing Charges, Maximum and Minimum Prices and Prices Obtained by the Producer and Paid by the Consumer with regard to Certain Commodities in Madras Province

Article	Marketing charges				Wholesale price trends			Price paid			Remarks
	Unit	Maximum	Minimum	Average	Unit	Peak	Lowest	Unit	To producer	By consumer	
		Rs. A. P.	Rs. A. P.	Rs. A. P.		Rs. A. P.	Rs. A. P.		Rs. A. P.	Rs. A. P.	
1 Paddy ..	Rs. 100 worth	4 5 6	1 13 8	3 0 8	1 md. of $82^2/_7$ lb. of rice	5 4 0	4 5 6	1 md. of $82^2/_7$ lb.	1 3 3	1 12 10	*Note:*—The information has been compiled from the Marketing Survey Reports published by the Agricultural Marketing Adviser, Delhi
2 Groundnut seeds	,,	6 13 10	2 10 5	3 15 10	Per ton	120 6 0	103 7 0	Rs. 100 worth	2 14 0	5 6 10	
3 Tobacco	,,	5 7 0	4 12 6	5 1 9	1 md. of $82^2/_7$ lb.	14 0 0	12 5 0	1 md. of $82^2/_7$ lb.	9 9 0	13 13 7	
4 Coconuts	,,	11 1 9	6 13 4	8 15 6	1,000 nuts	22 12 0	17 12 0	20 nuts	2 10 0	4 6 0	
5 Potatoes	Per md. of $82^2/_7$ lb.	4 11 0	4 8 0	4 9 6	Per md. of $82^2/_7$ lb.	4 0 0	2 13 0	Per md. of $82^2/_7$ lb.	2 4 3	4 2 2	
6 Oranges	Per 100	0 8 0	0 4 0	0 6 0	,,	15 5 4	6 14 10	Per 100	3 8 0	6 8 0	
7 Bananas	350 fruits	0 5 7	0 2 3	0 3 11	1,000 fruits	7 4 11	4 15 1	350 fruits	1 0 0	2 7 6	
8 Bengal-gram	Rs. 100 worth	26 8 0	14 14 10	20 11 5	Per md. of $82^2/_7$ lb.	3 8 6	2 9 3	Per md. of $82^2/_7$ lb.	2 1 0	2 12 8	Information relates to Punjab and Karachi

Statement supplied by courtesy of the Marketing Officer, Mysore State.

ment which is needed in all enterprises, a *sine qua non* for their success will be a strong combination of *all* the growers, and the obligation to deliver all their produce for sale through the Society, which should be fulfilled with steadfast loyalty by the producers or enforced by the rules or even by law. A well-known and almost classical example of such a Society is the California Fruit Growers' Exchange, which was the means of saving the industry from the crippling ruin which faced it. In India too several successful societies of the kind, though very much smaller in comparison, can be mentioned, but the scope for more is almost unlimited.

4. *The Putting Down of Malpractices in the Market*

Reference has already been made to the charges which are levied from producers when they have to market their goods. In addition to the levy, producers are also subjected to practices or 'malpractices' causing both annoyance and loss. To the extent that these charges can be reduced and the 'malpractices' put down producers stand to gain or get a better price for their produce. There are however two views on this question, one which makes out the merchant class as heartless and unscrupulous sharks and the farmer as a poor helpless victim, and the other making out that the farmer is no such ignorant fool but is a past master in the art of sophistication of produce and it is really this fact which forces the merchant to adopt counter measures, however improper they may be, by way of self-protection. Though these views are largely coloured by personal predilections, it cannot be gainsaid that there is much truth in both allegations. In practice, it will be a great advantage if an improvement can be effected on both sides, as it is a vicious circle, each being the alleged cause of the other. Mention may now be briefly made of what the alleged shortcomings are, specifically.

1. *Among Merchants.*—Of the first kind are: (1) the use of weights and measures which are not standard and which work always against the producer; in a survey made, some 69% of the scales used and 29% of the weights used were found to be incorrect; (2) even with these, further loss may accrue to the producer by skilful manipulation in weighing and measuring; (3) weighment or measurement in small units of a few pounds or seers each time instead of in large units like a cwt. or a bushel, by which practice a little is unduly gained each time a weighment is made; (4) settling prices with the purchasers 'under cover' so that the producer does not know exactly what price was realised by his produce; (5) condemning or crying down produce after approval of sample and settlement of rates and after the dumping down of the goods, thus forcing the producer to agree to a lower price as a Hobson's choice; (6) inclusion of a number of petty and unreasonable charges like *hamali*, weighman's wages, perquisites and wages to cleaning coolies at the weighing yard, samples at more than one stage, pickings in kind for odd but customary purposes, deductions for charity, temple or cow

protection fund, etc.; (7) deductions for moisture and possible loss on driage; (8) a big discount if payment of spot cash is to be made or in the alternative, delay of a month or more; and (9) above all, complete unity among brokers or traders, which puts the seller completely at their mercy without the possibility of obtaining any better treatment.

2. *Among Producers.—Per contra* it is contended on the other side that the producer resorts to all kinds of petty frauds principally by way of (1) adulteration of goods; (2) produce is moistened to the extent of heavily watering in order to increase the weight; (3) small sizes, inferior grades mouldy and stained stuff are concealed inside bales or bundles and even stones are sometimes included inside such bundles or trusses or bales, which are not usually opened and inspected; (4) seeds are cleverly included in articles sold usually in a de-seeded condition like tamarind; (5) produce is artificially coloured to imitate better grades; (6) old produce is passed off as new where this cannot be made out by appearance and so on. In the case of butter (and ghee) the adulteration reaches its peak, for materials are used which defy detection by even experts. It is also contended that merchants and brokers usually compete for the producers' custom and offer various inducements to attract and to retain it, that prices get known very quickly in the villages notwithstanding "under cover" transactions, and any hardship which may be caused is only when prices fall in the interval between one market day and the next, and lastly and above all it is the merchant who faces unavoidable risks of price fluctuations while the producer is well protected. Except that the producer has no organisation, it is contended against him that on the whole it is he who holds the stronger hand. Indeed it is even suggested that where producers' organisations do exist, monopolistic tendencies of an even more serious character, are developing, which place the consumer at a great disadvantage. It is difficult to assess or apportion the guilt of either party but there is much need and scope for improvement in marketing methods. For detailed information on this aspect of the subject in respect of many kinds of Indian produce, the reader is referred to the Reports on the Marketing Surveys of each of them published by the Government of India.

Regulated Market

It may be pointed out that as far as the mitigation of the hardships to the producers in the different markets is concerned, a system of "Regulated Markets" is being introduced with statutory provisions for regularising the methods and that a fair number of such large markets have already come into existence under this provision and others may follow. These provisions ensure the use of correct weights and measures, open bids, arbitration in respect of disputes about quality or other matters, etc., so that one main feature adverse to the producer is being eliminated.

Producers' Co-operative Societies

Many of the other features which will help in ensuring a better price for the farmer's produce which have been touched upon in this chapter can follow only as the result of the organisation of Farmers' Co-operative Societies, whether they be of the so-called "multi-purpose" type from which money can be borrowed, goods purchased, and produce sold, or held in storage against possible increase in prices, or those formed for any one single purpose. It may be even possible for these societies to own large mechanical outfits like tractors and tractor-drawn implements, sugarcane mills and jaggery boiling outfits, seed drills, threshing machines, winnowers, etc., and any such similar outfits which will be found useful for one or more village communities for common use. All over the world it is only with the weapon of combination and co-operative effort that producers have been enabled to reduce production costs by the use of labour-saving appliances on the one hand and to free themselves from their entire dependence on the trader and thereby to secure a better price for their produce on the other.

APPENDIX I

BOTANICAL NAMES OF THE PLANTS MENTIONED IN THE TEXT AND GLOSSARY OF VERNACULAR TERMS USED

Aloe	*Agave americana*
Areca	*Areca catechu*
Arhar (Rahar) ..	*Cajanus indicus*
Avare	*Dolichos lab-lab*
Avare	*Cassia auriculata*
Bajri	*Pennisetum typhoideum*
Barley	*Hordeum vulgare*
Bengalgram	*Cicer arietinum*
Berseem	*Trifolium alexandrinum*
Blackgram (Udid) ..	*Phaseolus mungo*
Brinjals	*Solanum melongena*
Bulb grass	*Cyperus rotundus*
Buttercup	*Ranunculus acris* L.
Castor	*Ricinus communis*
Cashewnut	*Anacardium occidentale*
Chillies	*Capsicum annuum*
Cluster bean	*Cyamopsis psoralioides*
Cocoanut	*Cocos nucifera*
Coffee	*Coffea arabica*
Coriander	*Coriandrum sativum*
Cotton D.A.	*Gossypium hirsutum*
Cowpea	*Vigna catiang*
Deccan hemp (Gogu) ..	*Hibiscus cannabinus*
Dekamalli	*Gardenia gummifera*
Docks	*Rumex* Spp.
Gingelli	*Sesamum indicum*
Ginger	*Zingiber officinale*
Groundnuts	*Arachis hypogea*
Greengram	*Phaseolus radiatus*
Hariali (Dub) grass ..	*Cynodon dactylon*
Honge (Karanj) ..	*Pongamia glabra*
Horsegram	*Dolichos biflorus*
Indigo	*Indigofera tinctoria*
Italian millet	*Setaria italica*
Jowar, Juar	*Andropogon sorghum*
Jute	*Corchus capsularis*
Kesari	*Lathyrus sativus*

Linseed	..	*Linum usitatissimum*
Maize	..	*Zea mays*
Mustard	..	*Brassica nigra*
Neem	..	*Melia azhadirachta*
Niger	..	*Guizotia abyssinica*
Onion	..	*Allium cepa*
Palmyra	..	*Borassus flabelliformis*
Peas	..	*Pisum arvense*
Pepper	..	*Piper nigrum*
Pillipesara	..	*Phaseolus aconitifolius*
Punnai	..	*Calophyllum inophyllum*
Ragi	..	*Eleusine coracana*
Ragwort	..	*Senecio jacobœa* L.
Rice	..	*Oryza sativa*
Safflower	..	*Carthamus tinctorius*
Sannhemp	..	*Crotalaria juncea*
Sarson	..	*Brassica napis*
Senji	..	*Melliotus parviflora*
Shaftal	..	*Trifolium resupinatum*
Sugarcane	..	*Saccharum officinarum*
Thistles	..	*Carduus arvensis* L., *Sanchus* Spp., *Cnicus acaulis* Hoffm. and others.
Tobacco	..	*Nicotiana tabacum*
Tur, tuver, togare	..	*Cajanus indicus*
Turmeric	..	*Curcuma longa*
Wheat	..	*Triticum sativum*
Wild date	..	*Phœnix sylvestris*
Yakka	..	*Calotropis gigantea*

Aslesha	(asterism)	in Hydræ	From	August 3 to 15
Aridra	,,	,, Orion	,,	June 22 to July 5
Maghe	,,	,, Leonis	,,	August 16 to 30
Poorvashadha	,,	,, Sagittarius	,,	December 29 to Jan. 10
Satabhishtak	,,	,, Aquarius	,,	February 19 to March 3

Chaitra	(month)	..	Commencing	April 13
Magha	,,	..	,,	February 13
Margasira	,,	..	,,	December 15
Phalguna	,,	..	,,	March 14
Pushya	,,	..	,,	January 14

Maidan—Open plain country

Malnad—Hilly forest country of heavy rainfall

Wodder—A navvy.

APPENDIX II

BOOKS, JOURNALS AND OTHER PUBLICATIONS CONSULTED

1. *The Climates and Weather of India, Ceylon and Burma,* by H. F. Blandford.
2. *Agriculture in Some of Its Relations with Chemistry,* by F. H. Storer.
3. *Soil Conditions and Plant Growth,* by Sir John Russell, D.Sc., F.R.S.
4. *The Soil,* by Prof. F. H. King.
5. *Physics of Agriculture,* by Prof. F. H. King.
6. *Irrigation and Drainage,* by Prof. F. H. King.
7. *The Soil,* by the late Sir A. D. Hall, revised by G. W. Robinson, M.A., Sc.D.
8. *Stephens' Book of the Farm,* by James Mac Donald, F.R.S.E.
9. *Elements of Agriculture,* by W. Fream, LL.D.
10. *Handbook of Indian Agriculture,* by N. G. Mukerji.
11. *A Text-Book of Indian Agriculture,* by J. Mollison, M.R.A.C.
12. *A Note Book of Agricultural Facts and Figures,* by R. C. Wood.
13. *A Note Book of Agricultural Facts and Figures,* by Primrose MacConnel.
14. *Soils of the Bombay Presidency,* by Dr. L. Sahasrabudhe.
15. *An Introduction to Tropical Soils,* by Dr. Vagelar, translated by Dr. H. Greene.
16. *Lift Irrigation,* by Sir Alfred Chatterton.
17. *D.P.W. Handbook of the Bombay Presidency.*
18. *Examination of Water for Sanitary and Technical Purposes.* by Dr. Leffmann.
19. *Hydrology and Ground Water,* by J. M. Lacey.
20. *Hydroponics,* 1946-47, Bulletin No. 1, issued by the Hydroponic Research Centre, Kalimpong, Darjeeling.
21. *Dry Farming,* by Dr. John A. Widtsoe.
22. *Landwirtschaftiche Geräte and Machinen,* by W. Strecker.
23. *Farm Machinery and Motors,* by J. W. Davidson and L. W. Chase.
24. *Power and the Plow,* by L. W. Ellis and A. Rumley.
25. *The Use of Fertilisers,* by A. Jacob, Ph.D. and V. Coyle, M.Sc.
26. *Commercial Fertilisers,* by Gilbert H. Collins, Ph.D.
27. *Anwendung künstlicher Düngemittel,* by Prof. Dr. Paul Wagner.
28. *Dictionary of the Economic Products of India,* by Sir G. Watt.
29. *Manual of Grasses of the U.S.A.,* by A. S. Hitchcock.
30. *Recent Advances in Agricultural Plant Breeding,* by H. Hunter and H. Martin Leake.
31. *Practical Plant Breeding,* by W. J. C. Lawrence, F.L.S.
32. *Plant Breeding,* by L. H. Bailey.

33. *Cyto-Genetics and Plant Breeding,* by S. N. Chandrasekaran and S. V. Parthasarathy.
34. *Rice in Madras,* by K. Ramiah.
35. *Fruit Fall and Its Control by Synthetic Growth Hormones,* by M. G. Vyvyan, M.A., D.Sc.
36. *Brihat Samhita of Varahamihira*, translated by Pandita Bhushana V. Subramanya Sastri, B.A.
37. *Management in Russian Industry and Agriculture,* by G. Beinstock, S. M. Schwarz and A. Yugow.
38. *Report of the Indian Delegation on Co-operative Farming in Palestine.*
39. *Punjab Village Surveys.*
40. *Post-War Studies,* No. 17, Farm Buildings, Ministry of Agriculture and Fisheries.
41. *Annual Reports of the Mysore Department of Agriculture.*
42. *Journal of the Mysore Agricultural and Experimental Union.*
43. *Mysore Agricultural Calendars.*
44. *Villagers' Calendar*, Madras Agricultural Department.
45. *Farm Implement News,* Chicago.
46. *Tropical Agriculturist*, Ceylon.
47. *Indian Weather Review,* 1939.
48. *Indian Farming.*
49. *Indian Journal of Agricultural Science.*
50. *Proceedings of the Indian Science Congress*: Presidential Addresses and Papers read at the Agricultural Section.
51. *Reports of Agricultural Marketing Surveys of the Government of India.*
52. *Agricultural Ledger.*
53. *Land and the Nation,* Rural Report of the Liberal Land Committee, 1923-25.
54. "*Agriculture*", The Journal of the Ministry of Agriculture, England.
55. *Reports of Subordinate Officers of the Department of Agriculture, Madras.*
56. *Some Important Insect Pests of Stored Grains and Their Control,* by B. Krishnamurti and D. Seshagiri Rao.

APPENDIX III

ELECTRO-CULTURE

IN the various chapters of the text, all the factors of crop production have been dealt with in a fairly comprehensive manner, including those that can be controlled and regulated by man and those capable of practical application in the field, and others like the climatic factors which in spite of their overshadowing importance are beyond human control. All these are factors which are well recognised as such and their effect on plant life in general and crop husbandry in particular is of a demonstrable character, and therefore admit of general acceptance, many of them being indeed as old as agriculture itself. There is, however, one factor, *viz.*, electricity, which although used in the service of man in practically every conceivable sphere of modern life, to such an extent that the present is referred to as the "age of electricity", yet remains a neglected and obscure factor as far as crop production is concerned. This is in spite of the fact that the idea of using electricity to stimulate plant life and increase crop production is a most alluring one and has engaged the attention of several persons, who have devised more than one method of applying it in practice. Very encouraging results are also reported to have been obtained, but somehow they have failed to carry conviction, and the attitude of the scientific world and of the practical agriculturist, may be said to be one of indifference and scepticism, positive unbelief and even of ridicule. In the result, the idea and the methods have not been pursued and developed and the field considered by enthusiastic advocates as a most fertile and promising one remains barren.

It happens furthermore that the subejct is seldom dealt with in any of the text-books on agriculture and it is therefore difficult to get at any information relating to the methods, their application or results. It may be deemed useful therefore to append the following brief account of the salient features of these methods which have come to be known as Electro-culture.

It is stated that the earliest known experiments were carried out in Edinburgh, by Dr. Mainbray, a Scottish physician in 1746, who demonstrated that electricity stimulated the growth of certain trees. In 1783, Berthelon experimented with agricultural crops and recommended its use as a remedy against fungus diseases and insect pests. Since then, off and on experiments have been carried out not only in Europe but in the United States, Canada, Australia and New Zealand, and it is claimed that the results have established "beyond doubt the beneficial effect of the application of electric stimulants to plant or seeds".

An astonishing instance of what appears to be an undoubted result of electricity on plant life is furnished by the following

account:—"The Avenue Louise in Brussels is lined with chestnut trees and an electric tramway runs along one side, but, strange to say, the chestnut trees on that side lose their leaves in August, then bud again in October, while those on other side keep their foliage till the end of the year, and only bloom again the following spring. It is believed that the electric current of the tramway, passing through the ground, affects the roots and causes this abnormal behaviour of the trees." (Frank A. King, *Wonders of the Tree World.*)

As regards the methods of application of the electric current, they fall into the following classes :—

1. *Illumination by Electric Light.*—Many forms of electric lights such as the incandescent, etc., have been tried and it is claimed that such electric light is to be regarded as a "valuable asset in the forcing of market gardens and green-house produce, and in producing fruits and flowers out of season".

2. *The Conduction of Atmospheric Electricity from Elevated Conductors to the Soil.*—"The general method adopted for the purpose is to attach a conductor to a tall tower and to connect this with buried plates or networks of wire. A cheaper method is to plant numerous metal stakes several feet along over the field to act instead of a tall conductor."

3. *Burying Plates of Copper and Zinc in the Soil, and Under the Soil as an Electrolyte.*—In one experiment in this class a copper plate 5′ long and 14″ wide was buried at one end of a plot and a similar plate of zinc at the other end 200 yards away, and these plates were connected by an overhead insulated wire. Smaller plates can, however, be used also, and galvanised iron can be used instead of zinc, making the method thereby a very cheap and simple one.

4. *Passing a Current through the Soil from External Sources.*—This was the method adopted in the earliest experiment. It is, however, said to be less promising than the others.

5. *Silent Discharge from Antennæ or Overhead Network of Wires.*—The current may be derived from various sources, such as atmospheric electricity, dynamos driven by a small engine or town supply.

As regards atmospheric electricity, the method consists in spreading over the plants a network of wire so highly charged with electricity that it is discharged into the air and increases the current passing from the air to the plant to about ten thousand times its normal value.

In regard to the use of dynamos and of town supplies the general method is to pass a direct current (not alternating) of about 100,000 volts in the overhead wires, causing them to glow in the dark and to discharge with a slight hissing noise. The equipment has been found too costly, and the wires a hindrance to farm operations. Further, it has been found that there is an optimum value of the current for each kind of plant and at different stages in growth, and that if the value is overstepped, the plant may be

harmed, and that there are other interfering factors also, such as the dryness of the weather.

6. *Electro-Chemical Treatment of Seeds.*—It is in this phase of electro-culture that the most practical developments appear likely to take place, both on account of the simplicity of the method and on account of the striking results obtained, one of which at least has been confirmed by trials conducted by the British Board of Agriculture.

The method adopted is merely to pass a current through a solution in which the seeds are immersed. Results in the case of wheat showed an increase of quite 10½ bushels an acre, a figure which will be considered unbelievable were it not that the trials were conducted by this official body. The increase was not merely in the yield but also in the leaves, quality of the seed and in the quantity and quality of the straw. It is also stated that such treatment promotes germination, growth, resistance to disease, earliness of maturity etc., besides modifying the quality of the grain and the straw.

(Extracted from Article on "Electro-Culture" by J. F. Rae in the *Journal of Agriculture,* Victoria, Vol. 18, Part 7.)

In India the subject has been pursued with great enthusiasm within recent years by Dr. S. S. Nehru, a member of the Indian Civil Service, who has adopted a very simple and inexpensive technique and who claims to have obtained results so remarkably striking as to be almost unbelievable. It is stated that many people have followed this method both in India and abroad, and obtained equally striking results, although they have not received recognition from agricultural experts or the various experimental stations or other agricultural institutions. He has adopted the method not only in respect of crop yields but also of the prevention or cure of insect pests and diseases, in the improvement of the quality of crops, and even in the cure of diseases of cattle.

The technique, adopted by him, is in his own words the following:

"Plants: (1) *Radiomagnetic.*—Seed is sown in a bed provided with a sheet of iron wire-netting, mesh ½". For a plant or tree a jacket or apron is formed 1" to 1' wide, depending on the girth. For individual branches of a tree a collar of the same wire-netting is formed.

(2) *Preliminary treatment of seed before sowing,* either dry, by spreading it out in a thin layer on an insulated metal plate and then giving the plate a high tension spark of say, 2,000 volts for one minute and then sowing the seed *without touching*, or wet, by soaking the seed in electrified water in an insulated vessel for 1 to 2 hours and then sowing the seed without touching, as before.

(3) *Agaskarising* the plant or giving it electrified water. Whenever a growing plant is given such a mantle of electrified water, its growth is increased. This is much more than irrigation, which is watering the roots. Water is electrified by taking it in an

earthenware container, placing it on a rubber mat, dipping one end of a high tension cable into the water while the other end is hooked on to the ignition plug of a motor car and running the engine for a ¼ minute. A complete set of such pitchers containing as many as 100 gallons can be electrified at once by dipping one end of a wire into each, collecting and connecting the other ends together and then using a cable in the same way and running the engine as above.

(4) *Interculture* of the growing plant with plants which are rich in M-rays or Gurwitch rays or ultra-violet rays, like onion and other root crops.

(5) Combination of the above methods."

These are important details and variations in practice to suit different conditions, whether in respect of crops or of animals, which are appended to the above brief description, but which we do not need to transcribe here. Dr. Nehru has been tireless in his propaganda and displaying the zeal of an evangelist in popularising the method. As he says himself, the methods are extremely cheap, simple and harmless, and, considering the results claimed, are of great practical value. They deserve trials by agricultural officers so that their correctness may be tested in the usual standard manner, and their true value determined. Reference is invited to a paper published by him, in the *Journal of the Royal Society of Arts*, of October 1936, Vol. LXXXIV, No. 4380, from which the above information has been extracted and which may be consulted for a full account.

INDEX

(Figures refer to pages in the Text)

A

B

B—*Contd.*

C

C—*Contd.*

D

D—*Contd.*

E

F

F—*Contd.*

G

G—*Contd.*

H

I

I—*Contd.*

N

O

P

P—*Contd.*

Q

R

S

S—*Contd.*

S—*Contd.*

T

U

V

W

W—*Contd.*

X

Y

Y—*Contd.*

Z

469–61. Printed at The Bangalore Press, Bangalore City, by T. K. Balakrishnan, Superintendent.

Akjaz